The preparedness and response of the population of Lyttelton, New Zealand, and surrounding areas, for and to hazards

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by

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Abstract

Small, tight-knit communities, are complex to manage from outside during a disaster. The township of Lyttelton, New Zealand, and the communities of Corsair Bay, Cass Bay, and Rapaki to the east, are especially more so difficult due to the terrain that encloses them, which caused them to be cut-off from Christchurch, the largest city in the South Island, barely 10 km away, after the M_w 7.1 Darfield Earthquake and subsequent Canterbury Earthquake Sequence.

Lyttelton has a very strong and deep-rooted community spirit that draws people to want to be a part of Lyttelton life. It is predominantly residential on the slopes, with retail space, service and light industry nestled near the harbour. It has heritage buildings stretching back to the very foundation of Canterbury yet hosts the largest, modern deep-water port for the region.

This study contains two surveys: one circulated shortly before the Darfield Earthquake and one circulated in July 2011, after the Christchurch and Sumner Earthquakes. An analytical comparison of the participants' household preparedness for disaster before the Darfield Earthquake and after the Christchurch and Sumner Earthquakes was performed. A population spatiotemporal distribution map was produced that shows the population in three-hourly increments over a week to inform exposure to vulnerability to natural hazards.

The study went on to analyse the responses of the participants in the immediate period following the Chrsitchurch and Sumner Earthquakes, including their homeward and subsequent journeys, and the decision to evacuate or stay in their homes. Possible predictors to a decision to evacuate some or all members of the household were tested.

The study also asked participants' views on the events since September 2010 for analysis.

Definitions and/or Abbreviations

Some of the major earthquakes mentioned in this thesis that have struck the Canterbury region since 4th September 2010 have been given names in the literature, but others have not. On occasion, it is more appropriate to refer to the date the earthquake occurred, e.g. the *February earthquake*. The following names have been used in this thesis:

Table 0-1-1 : Names of major earthquakes used in this thesis

Name[1] [Fault]	M_w	Depth (km)	Date and time – NZ Local time YYYYMMDD HH:MM	GNS Science reference number
Canterbury Earthquake Sequence			20100904 onwards	
Darfield Earthquake [Greendale Fault]	7.1	10	20100904 04:35	3366146
Boxing Day Earthquake [Christchurch Fault]	4.9	5	20101226 10:30	3437105
Christchurch Earthquakes [Port Hills Fault]			20110222	
I	6.3	6	20110222 12:51	3468575
II	5.8	6	20110222 13:04	3468581
III	5.9	7	20110222 14:50	3468635
Sumner Earthquakes [Sumner Fault]			20110613	
I	5.9	9	20110613 13:01	3528810
II	6.4	7	20110613 14:20	3528839
Pre-Christmas (2011) Cluster [Pegasus Bay Seismicity Zone]			20111223	
I	5.9	10	20111223 13:58	3631359
II	5.3	10	20111223 14:06	3631363
III	6.0	7	20111223 15:18	3631380
IV	5.1	11	20111223 16:50	3631432

[1] Earthquakes are usually named according to the closest named important locality or geographical location to the epicentre. Even though the earthquakes that occurred on 22nd February 2011 happened away from Central Christchurch, it was the effect they had on the complete city that is reflected in the name. Some of these earthquakes are not named officially, or are referred to as part of a cluster or swarm, or the date they occurred. Likewise, the names of faults take time to become established in literature.

Table 0-1-2 : Acronyms

Acronym	Long form
CCC	Christchurch City Council
CDEM	Civil Defence Emergency Management
CERA	Canterbury Earthquake Recovery Authority
CPSZ	Canterbury Plains Seismicity Zone
DBH	Department of Building and Housing
DoC	Department of Conservation
ECan	Environment Canterbury
ESRI	Environmental Sciences Research Institute. A vendor of GIS software.
EQC	EarthQuake Commission
GIS	Geographic Information System. A system for storing and manipulating geographical information on a computer.
GDP	Gross Domestic Product
GNS	Te Pū Ao. The Institute of Geological and Nuclear Science Limited, established in 1865 and one of New Zealand's Crown Resource Institutes.
GNSS	Global Navigation Satellite System
GST	Goods and Services Tax
HFA	Hyogo Framework for Action
ICSU	International Council for Science
IESE	Institute of Earth Science and Engineering
IRDR	Integrated Research on Disaster Risk
ISDR	International Strategy for Disaster Reduction
KML	Keyhole Markup Language. KML is a file format used to display geographic data in an Earth browser, such as Google Earth.

Acronym	Long form
LINZ	Land Information New Zealand
MCDEM	Ministry of Civil Defence Emergency Management
MMI	Modified Mercalli Intensity scale
M_w	Moment Magnitude Scale (MMS). Used to measure the size of earthquakes in terms of energy released.
NHRC	Natural Hazards Research Centre
NZD	New Zealand Dollar
NZTA	New Zealand Transport Agency
PBSZ	Pegasus Bay Seismicity Zone
PHGG	Port Hills Geotechnical Group
PSHA	Probabilistic Seismic Hazard Assessment
TCLEE	Technical Council on Lifeline Earthquake Engineering
UoC	University of Canterbury
USD	United States Dollar
WSPA	World Society for the Protection of Animals

1 Introduction

1.1 Introduction

Lyttelton (pop. 3’075) (Statistics New Zealand 2006c) is a small satellite township to the South of Christchurch, New Zealand. It is of high strategic importance to Christchurch City (pop. 348’435) (Statistics New Zealand 2006b) and the surrounding region due to its deepwater port.

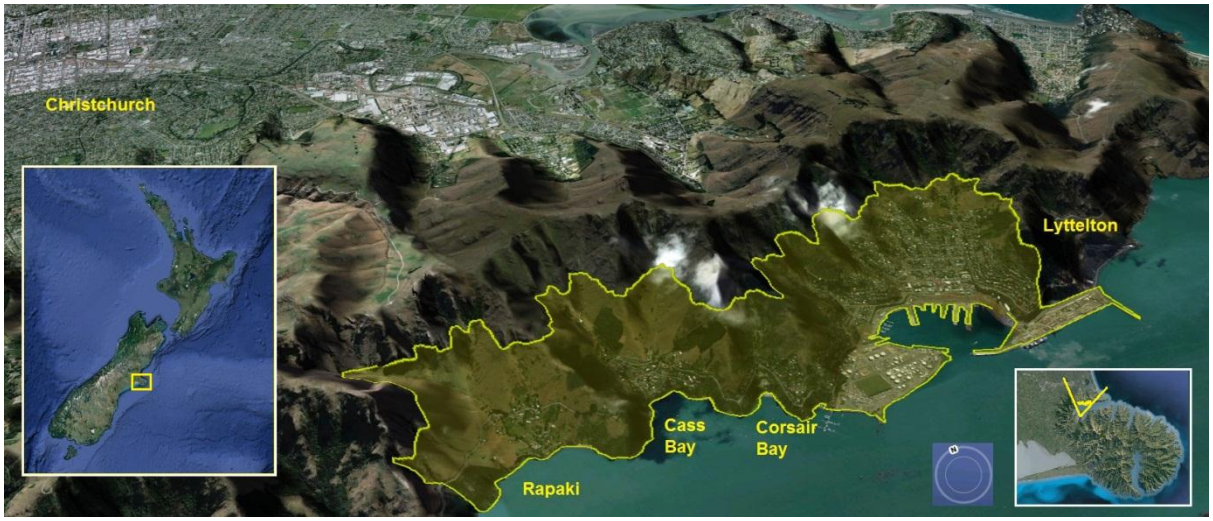


Figure 1-1 : Study area in context of New Zealand

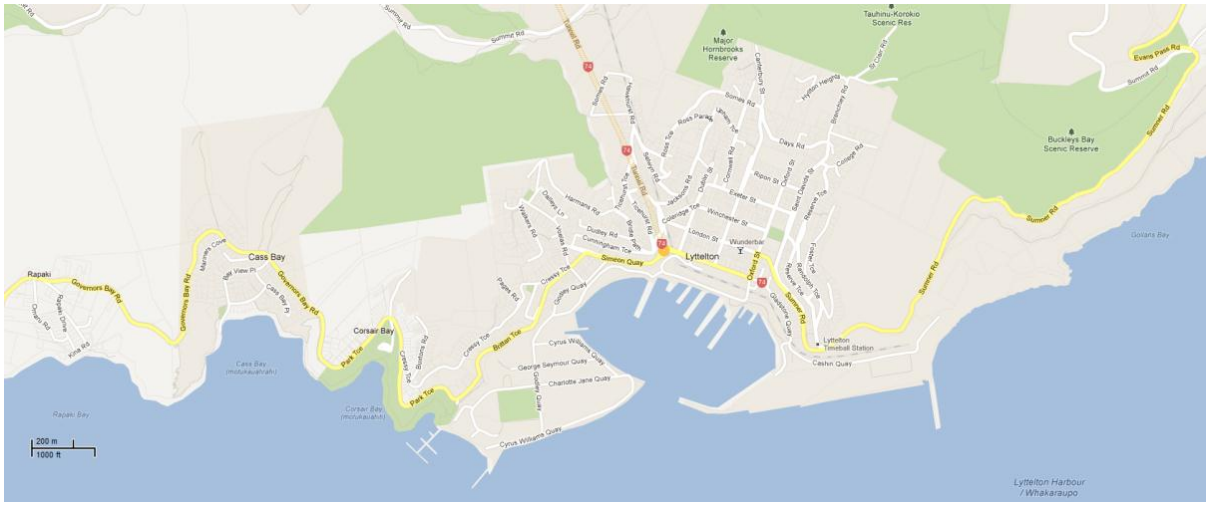


Figure 1-2 : Map of Study Area

There have been various studies commissioned to analyse the continuation of port operations after the occurrence of natural hazard events. Most are unpublished, embargoed, or confidential due to commercial sensitivity. However, no known previous

analysis of population vulnerability has been undertaken for Lyttelton. It is this gap which this thesis addresses; a study of the resident population, their preparation for and needs during a period of calamity. Due to the timing of the research and unfolding events, this study takes advantage of a unique opportunity to compare the pre-disaster planning and preparedness of one community with post-disaster actions within one year over three major disasters.

Over the course of this study, the 2010-onwards Canterbury Earthquake Sequence has been affecting the region: 4th September 2010 Darfield Earthquake; 26th December 2010 Boxing Day Earthquake; 22nd February 2011 Christchurch Earthquake; 13th June 2011 Sumner Earthquake; and, 23rd December 2011 Pre-Christmas Earthquake. All were felt in Lyttelton and most caused damage or fear.

Lyttelton lies within the extinct Lyttelton Volcano, between steep hill slopes to the North and the harbour to the South (New Zealand Geological Survey 1988). Prior to the recent 2010/2011 Canterbury Earthquake Sequence, the steep slopes above residential areas had the potential to generate rock falls during an earthquake (Elder et al. 1991); to the East and West, the access roads pass under high and crumbling basaltic cliffs (Crampton 1985): the earthquakes demonstrated the accuracy of these findings. Above the township, tunnel gullies in the loess/loess colluvium affect down-slope properties (Yetton 1986). Liquefaction of the reclaimed areas of the harbour, especially in and around the dangerous goods wharf, could have devastating consequences to many residents, especially given the proximity to the Lyttelton Road Tunnel portal, should a chemical spill or explosion eventuate. Another recent event raised the concern of the hazard of a tsunami generated in the Pacific Ocean entering the harbour. In 1868, the M_w 8.5 Arica, Chile Earthquake (National Oceanic and Atmospheric Administration (NOAA) 2012) on the west coast of South America produced 6 m waves in Lyttelton Harbour, in 1960 the M_w 9.5 Puerto Montt, Valdivia Earthquake in Chile (National Oceanic and Atmospheric Administration (NOAA) 2012) generated 5.5 m waves in the harbour (Elder et al. 1991), and more recently, on 27th February 2010, a M_w 8.8 earthquake in Concepcion, Chile (National Oceanic and Atmospheric Administration (NOAA) 2012) produced a surge in Lyttelton harbour that, at tidal extremes, emptied Cass Bay and overtopped the jetty at Governor's Bay (stuff.co.nz 2010b).

This study has identified 1’400 households in the study area: Lyttelton township is home to 876 households, more than half of which have children (Statistics New Zealand 2006c).

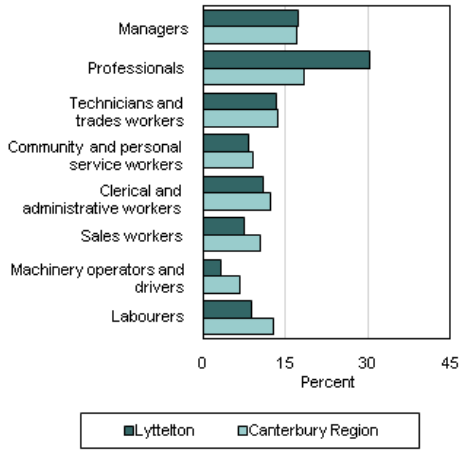


Figure 1-3 : Occupation - Lyttelton vs. Canterbury (Statistics New Zealand 2006c)

It contains a population from mixed socio-economic backgrounds: professionals, tradespeople, retirees, and artisans. It has a combination of service, manufacturing, and entertainment industries. It is a community in its own right but also a satellite town for Christchurch. Lyttelton is also a favourite entertainment, recreation and relaxation destination at evenings and weekends for residents of Christchurch and beyond. It is a transit town for those passing through the port. This makes the momentary population neither static nor homogenous.

The community has a high degree of social connectedness and cohesiveness, with a strong culture of volunteering. The Lyttelton Fire Brigade, Order of St John Ambulance service, Civil Defence, the Timebank and Project Lyttelton are among some of the local groups. There is a high degree of community pride and identity (CCC 2011b).

Although topographically constrained, Lyttelton is topologically well connected to neighbouring communities over three main vehicular access routes: Evans Pass (closed since the Christchurch Earthquake), Governor’s Bay Road, and the Lyttelton Road Tunnel. There are numerous foot tracks, the Bridal Path Track being the best-known and best maintained. The Lyttelton Railway Tunnel caters exclusively for freight and coal trains. Finally, the ferry to Diamond Harbour offers pedestrian and bicycle access. With a growing and dynamic population, there is little redundancy in the capacity of existing transport infrastructure in case evacuation or emergency-services ingress is required.

This rich mix of population and environment in such a small area has made this study both possible and convenient.

Since the Darfield Earthquake, Lyttelton has continued to suffer from a collapsing infrastructure. Many heritage buildings (Burgess 2009a) (some dating from the founding of Port Cooper, as Lyttelton was originally known, but mostly those rebuilt after the devastating fire of 1870) that survived with minor damage from the Darfield Earthquake were badly damaged in the Christchurch Earthquake, and the following Sumner Earthquake caused many to collapse or be deemed unable to be salvaged, and have been or will be demolished (CCC 2011b)(see Figure 1-4). The Lyttelton Timeball Station, and all of the town's oldest churches (including Canterbury's oldest stone church, the Holy Trinity) have collapsed.

Figure 1-4 : Map of demolished buildings in Lyttelton town centre (as of November 2011) (CCC 2011b)

Lyttelton was isolated from Christchurch immediately after the main Darfield Earthquake and the Christchurch Earthquake, as the Lyttelton road tunnel was closed and Evan's Pass road was blocked through rock fall. The town suffered power, telecommunication, and water supply failures. Road infrastructure was badly damaged and some roads impassable. It was difficult for households to know what was happening and to decide whether or not to stay or evacuate, even if they could.

Due to the social capital built up in Lyttelton, the community came together and displayed a high degree of resilience. The Lyttelton festival of Lights was due to be held on the weekend of 26th February 2011, at the same time as the inaugural visit to Lyttelton of the Queen Mary 2 cruise ship.

1.2 Objectives of this research

This study is an analysis of the preparedness for and response to impactful natural and manmade hazards by the resident population of Lyttelton and surrounding areas. Due to the timing of 2010 – present Canterbury Earthquake Sequence it has been possible to compare the community's planned response prior to the Darfield Earthquake with the actual response following the Christchurch and Sumner Earthquakes.

The objectives of this research are to:

1. Examine the preparedness of the resident population of Lyttelton and surrounding area for a natural or manmade disaster;
2. Examine the vulnerability of the resident population of Lyttelton and surrounding area to impactful disaster; and,
3. Examine the immediate response of the resident population of Lyttelton and surrounding area to recent disasters.

1.3 A multi-disciplinary approach

The study has taken a multi-disciplinary approach of physical hazard analysis, demographics, and social science methods, under a common approach to hazards. This study has been handled as neither a social sciences nor a psychology research topic, but it is unavoidable in the context of the research to touch on the human response: vulnerability of a population is dependent on socioeconomics as well as natural hazards. The definition of a disaster, as used by this study, refers to this socioeconomic relationship.

In the wake of the Kobe, Honshu Earthquake in Japan in 1995, the World Conference on Disaster Reduction (18th – 22nd January 2005, Hyogo, Japan) provided a unique opportunity to promote a strategic and systematic approach to reducing vulnerabilities and risks to hazards. It underscored the need for, and identified ways of, building the resilience of

nations and communities to disasters. This was embodied in the Hyogo Framework for Action (ISDR 2005).

An inter-disciplinary approach is also suggested by the International Council for Science (ICSU) (International Council for Science 2008).

1.4 Composition of the thesis

The thesis is composed of eight parts. This first chapter introduces the thesis and establishes a literature review of current knowledge of the preparedness for and response of populations to impactful hazardous events.

Chapter two examines the natural and manmade hazards that could impact the study area.

Chapter three explains the methodology employed to collect data to support the research.

Chapter four examines the exposure of the population to hazardous events, including the dispersion of the population throughout a typical week, leading to a model of vulnerability of the population to such hazardous events.

Chapter five examines the preparedness of the households within the study area for an impactful hazardous event, prior to the Darfield Earthquake on 4th September 2010 and after the February and June 2011 aftershock events, including households' plans and supplies.

Chapter six examines the movement of the population immediately after the February and June 2011 aftershock events.

Chapter seven examines the evacuation of affected households and the triggers that could precipitate a household to evacuate in future events.

Chapter eight concludes the research and makes recommendations for future research.

1.5 Literature Review

Due to the compounding factors facing the resident population of study area (loss of home, loss of neighbourhood, loss of facilities), it is important to understand from contemporary hazard and disaster literature how to approach this research.

International terminology used to define natural hazards can be highly variable and ambiguous. This review takes some of these definitions, compares them, and then chooses the definition which will be applied to this study.

This review has been undertaken to inform methodology and to guide interpretation of the results.

1.5.1 Disasters

To provide context, it is important to differentiate between an emergency, an incident, and a disaster.

A disaster is not simply a bigger everyday emergency: almost all researchers and many policy and operational personnel in emergency planning and managing agencies now recognise and make that distinction, seeing a quantitative and qualitative difference between routine accidents and disasters (Quarantelli 2000).

(Reid & van Niekerk 2008) define an incident as a relatively minor occurrence or episode of brief duration and that may have a potential to escalate. It is of limited magnitude and does not exceed the response capabilities of single response agencies or those agencies acting in support of the primary response agency.

The most widely cited definition of a disaster in the social sciences is the one developed by (Fritz 1961), who defined disaster as:

> *An event, concentrated in time and space, in which society, or a relatively self-sufficient subdivision of society, undergoes severe danger and incurs such losses to its members and physical appurtenances that the social structure is disrupted and the fulfilment of all or some of the essential functions of the society is prevented.*

The ISDR (ISDR 2007) defines a disaster as:

> *A serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources.*

(Mileti 1999) asserts that natural disasters are simply recurrent events in natural ecological cycles, without respect to social repercussions, but this view is not held by all.

(Quarantelli 1998) points out that a hazards perspective focuses on the hazard – earthquakes, tornadoes, floods, and so forth – and understanding the phenomena. Although there may be a concern with social and other issues, the real emphasis is on the processes associated with the target agent. Indeed, he points out that that some phenomena studied legitimately as disasters have no identifiable originating agent (Quarantelli 2005), such as famines or computer system failures.

This study favours the definition of a disaster as when there has been large-scale injury, death, or disruption (Smith & Petley 2008). (Quarantelli 2005) points out that, firstly, disasters are inherently social phenomena: it is not the hurricane or storm surge that makes the disaster; these are the source of the damage. The disaster is the impact on individual coping patterns and the inputs and outputs of the social system. Secondly, the disaster is rooted in the social structure and reflects the processes of social change. It is from these features of the social system that we find vulnerability to the particular source. (Wisner et al. 2004) have proposed a framework representing vulnerability in the context of the social causation of disasters (see Figure 1-5).

This study follows the social vulnerability approach by analysing the preparedness to and response of the study population, including the decisions concerning evacuation of individuals and households.

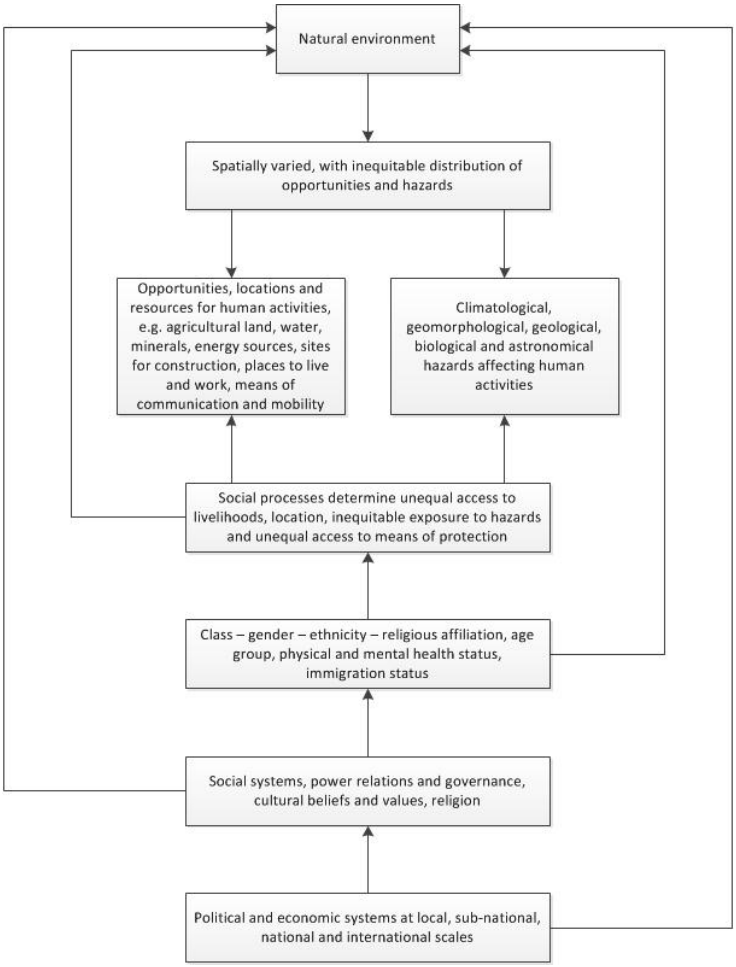


Figure 1-5 : The social causation of disasters (Wisner et al. 2012)

1.5.2 Hazard

A hazard is best comprehended as a naturally occurring or human-induced process or event that has the ability to generate loss and damage in the future. A natural hazard is a causative factor in any natural disaster, and hazards to human life are rated as the highest priority ahead of environmental modification and property damage (Smith & Petley 2008).

The ISDR (ISDR 2007) defines a hazard as:

> *A dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.*

The hazards of concern to this study, as stated in footnote 3 of the Hyogo Framework (ISDR 2005), are "… hazards of natural origin and related environmental and technological hazards and risks."

1.5.3 Risk

Disasters are usually not regular occurrences: they happen uncontrollably. People do not normally live as though they will encounter an imminent disaster situation: they ascertain the risk of a hazard turning into a disaster for them and behave accordingly.

Risk is often used synonymously, albeit incorrectly, with hazard. They differ in that risk takes into account the extra implication of the chance of an event actually occurring (Smith & Petley 2008) and portrays the human response to the hazard in question. A disaster is the realisation of a hazard and the consequence of the hazard event.

Risk has been defined as the product of the likelihood or probability of a hazard occurring and the adverse consequences from the event and is viewed by many as simply our exposure to hazards. Simply stated,

$$Risk = (Likelihood\ or\ Probability)\ x\ Consequence \quad \text{Eq-1}$$

This approach is based on the Royal Society Study Group defining risk as:

> *The probability that a particular adverse event occurs during a stated period of time, or results from a particular challenge. (Royal Society 1993)*

The Society provides a basis for an analysis of risks associated with hazards by measuring the likelihood and consequence of hazards in the community.

Risk can also be explained as a product of the hazard that may threaten a population, the vulnerability of the population to the hazard, and the exposure of the population to the hazard (Kron 2002).

$$Risk = Exposure\ x\ Vulnerability\ x\ Hazard \quad \text{Eq-2}$$

Risk, as it pertains to hazard management, is defined 'as the chance of something of human value being exposed to a natural hazard with negative outcomes' (Keey et al. 2000; Smith & Petley 2008).

The amount of risk is also affected by time and space: where the necessary components of the formula are, and when in relation to each other. E.g., a popular river-side Summer camp site would present a lower risk during a flood in Winter because the exposure to something of human value would be negligible.

Therefore, we modify (Eq-2) to be:

$$Risk = f(time, space) \cdot f(Exposure, Vulnerability, Hazard) \quad \text{Eq-3}$$

It is this latter definition (Eq-3) which shall be used in this study.

1.5.4 Exposure

Exposure is a component of risk, and refers to that which is affected by natural disasters, such as people and property (ADRC 2005). Exposure has two characteristics: physical presence and temporal presence.

The physical characteristics of exposure relates to the spatial relationship between that exposed and the hazard. Buildings and other permanent infrastructure are immovable, so may be continuously exposed to a hazard. People and cars are mobile, therefore their immediate, physical exposure corresponds to the risks in the environment where they currently are.

The temporal characteristics of disasters are also crucial. The season they occur, day of the week, time of day (Wisner et al. 2004). For example, in the harsh winter conditions of the Armenia Earthquake of 1998 few survived, while in warmer climates or seasons, trapped people stand a greater chance of surviving until rescued (Noji 1997). There are festivals, market days, and national holidays that concentrate large numbers of people in particular places on specific dates. Finally, the time of day the disaster occurs at is of critical importance: whether people are at home, commuting, or at work, school, or shopping affects the exposure to the disaster.

Growing exposure and delays in reducing vulnerabilities result in an increased number of natural disasters and greater levels of loss (ADRC 2005).

1.5.5 Vulnerability

(Alexander 2000) distinguished between risk and vulnerability, noting that:

> *Vulnerability refers to the potential for casualty, destruction, damage, disruption or other forms of loss in a particular element: risk combines this with the probable level of loss to be expected from a predictable magnitude of hazard (which can be considered as the manifestation of the agent that produces the loss).*

This definition does not take into consideration the socio-economic or political constraints imposed on certain members of the community, especially in less-developed communities.

This study will therefore use the following definition of vulnerability (Wisner et al. 2004):

> *The characteristics of a person or group and their situation that influence their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard (as extreme natural event of process).”*

Vulnerability can reveal itself in many forms:

- Physical
- Social
- Educational
- Financial

1.5.5.1 Physical vulnerability

Physical vulnerability represents threats to physical structures and infrastructures, the natural environment, and related economic losses (Perry & Mushkatel 1984).

1.5.5.2 Social vulnerability

Social vulnerability represents threats to the well-being of human populations (e.g. deaths, injuries, other medical impacts, disruptions of behaviour and system functioning) and related economic losses. Social vulnerability also includes the relative potential for physical

harm and social disruption to subpopulations of societies and their larger subsystems based on socioeconomic status, age, gender, race and ethnicity, family structure, residential location, and other demographic variables (Perry & Mushkatel 1984).

1.5.5.3 Educational vulnerability

Educational vulnerability represents threats that are unforeseen, i.e. the person or community has not learned about hazards they may face, either willingly or because the information has not been communicated. If someone is not informed of a hazard their hazard perception is reduced, and the choices available to them to mitigate the risk is similarly reduced (OECD 2010).

The presence of the unknown can be caused through lack of situational awareness of a hazard: people may be unfamiliar with the hazards of their immediate environment, or only familiar within the confines of a restricted, previous non-hazardous exposure, e.g. a mountain pass during benign weather conditions, or a riverside camping ground during the summer dry season. To avoid these gaps in knowledge of hazards in a particular location or situation, (Hewitt & Burton 1971) studied “all hazards-at-a-place” instead of considering each hazard in isolation. A major emphasis is the importance of the co-existence in time and space of a natural event and a human use domain as the basis for a multi-disciplinary approach to hazards study.

Complicating this simple notion is the exposure of the homes people return to and shelter in, and the roads and bridges they travel over: for example, a family holidaying overseas returning to their devastated home after an earthquake may make decisions prior to returning not being aware they may not be able to live in their home.

1.5.5.4 Financial vulnerability

Financial vulnerability may affect the individual, the household, the community, or even the State (Mechler et al. 2006). Lack of funds reduces the choices an individual or organisation can make, increasing their vulnerability.

1.5.6 Risk perception

How one perceives the adverse impacts of risk, either from an individual, organisational, or societal perspective, certainly influences strategies to address risk of natural hazards: to say the least, how risk may be perceived and the process for analysis will shape individual and institutional approaches to deal with risk (Hewitt & Burton 1971; Pine 2009).

Recent research found that, prior to the Darfield Earthquake, residents in Christchurch, Wellington, and Palmerston North were equally aware of earthquake information, yet those from Christchurch found it less relevant to them. Further analysis showed that those who knew people in Christchurch saw the risk of another earthquake in Canterbury as higher than those who did not, but did not see the risk of another earthquake in their own city as higher than those who did know anybody in Christchurch (McClure et al. 2011).

People in regions that are objectively deemed a lower risk than other regions appear to think that they are not at risk at all – they think the hazard will strike the higher risk region first. This line or reasoning can have disastrous consequences, because people think they do not need to prepare (McClure et al. 2011).

1.5.7 Comprehensive Emergency Management (CEM)

Comprehensive Emergency Management (CEM) was adopted in the New Zealand emergency management setting with the advent of the Civil Defence and Emergency Management (CDEM) Act (2002). The CDEM Act is applied to natural and man-made hazards that result in emergency situations. These may be of rapid onset such as earthquake, warned onset such as volcanic eruption, wildfire, or far-field tsunami, or slow onset such as a pandemic or drought.

Civil Defence Emergency Management includes the planning, organisation, coordination, and implementation of measures designed to guard against, prevent, reduce, or overcome any harm or loss associated with any emergency (CDEM Act, 2002). CEM comprises the "4Rs" that make up the phases of emergency management activities; these being:

- Reduction (mitigation) — Activities that reduce the degree of long-term risk to human life and property arising from natural and man-made hazards. This

includes identifying and analysing long-term risks to human life and property from natural and man-made hazards and taking steps to reduce these risks by reducing the likelihood and magnitude of their impact.

- Readiness (preparedness) — Activities that develop operational capabilities for responding to an emergency. For individuals and households, this also means preparing an emergency inventory of supplies, and an action plan for meeting and possible evacuation, without an expectation of external assistance.
- Response — Activities taken immediately before, during, or directly after an emergency that can save lives, minimize property damage, or improve recovery.
- Recovery — Activities that stabilize the affected community and assure that life support systems are operational, and longer term actions for community rehabilitation and restoration. This restoration needs to have a Reduction focus. It is important that the same hazard vulnerable community is not rebuilt (Build Back Better).

The four phases are interrelated and the effectiveness of each phase affects and is impacted by each other phase (Petterson 2009). This study concentrates on the Readiness[2] and Response phases as addressed by and to the population, but by the very nature of the 4Rs, Reduction and Recovery are not entirely excluded.

[2] In the international literature, *readiness* is referred to as *preparedness*. Preparedness shall be used in this thesis.

Figure 1-6 : Emergency Management Phases (Julian Idle)

1.5.8 Preparedness

Once the risk of a disaster for a population has been ascertained, a plan to mitigate that risk should be prepared. If risks cannot be reduced effectively, a plan to prepare for the disaster by increasing resiliency, response, or recovery affectivity should be drawn up.

(Russell 1995) has shown that pre-earthquake preparedness may be predicted by home ownership, income, education, marital status, number of children at home, number of years in the neighbourhood, and the number of earthquakes experienced. Post-earthquake preparedness may be predicted by proximity to the earthquake epicentre, earthquake-related experiences, fear, and levels of pre-earthquake preparedness.

Of particular interest informing this research (due to the many disasters that occurred in quick succession affecting the study population) is a survey (Bourque et al. 1973) conducted after the 9th February, 1971 San Fernando – Sylmar, CA Earthquake [M_w 6.5 (MM XI), 65 deaths, 2000 injured, USD 505M damage to property] (National Oceanic and Atmospheric Administration (NOAA) 2012). This found that 11% of a random sample of Los Angeles County residents reported some form of emergency preparations. Six years after the Sylmar Earthquake and about a year after the announcement of the discovery of the Palmdale bulge (Holdahl 1982), thought to be a precursor to a local and damaging earthquake, a further study (Turner et al. 1986) found fewer than 11% of a random sample of respondents in Los Angeles County reported some form of emergency preparations. Despite the recency

of the Sylmar Earthquake and the recent public announcement of the Palmdale bulge, the level of earthquake preparedness had not increased but had decreased.

A further study, within a month after the 28th June 1992 Landers, CA Earthquake [Mw 7.6 (MM IX), 3 deaths, 400 injuries, USD 92M damage to property] in Southern California, found that preparedness rates had risen to 27% for Northern Californians and 33% for Southern Californians, reinforcing the correlation between proximity to the earthquake epicentre as a prediction of preparedness as postulated in (Russell 1995). However, (Mulilis & Duval 1992; Mulilis & Duval 1991) suggest that experiencing a recent damaging earthquake does not seem to be adequate to inspire preparedness activities. Rather, motivation is provided by subjective and objective impact of the earthquake on that individual's life as represented by the amount of earthquake damage experienced, the level of fear during the shaking, and thoughts of it afterward, and whether evacuation was necessary; this motivation may result from increased perceived earthquake vulnerability. This is reinforced in (Awasthy 2009), as what helps explain preparedness evolves from a complex and diverse set of factors; stocking up on provisions stems from how individuals acted in previous disaster situations, knowing the survival skills needed in emergencies being explained by accessibility to this knowledge, planning for emergencies being related to religious-cultural attitudes, and exhibiting protective behaviour being correlated to amounts of disposable income, nationality, and risk perceptions.

The stress-appraisal model (Lazarus & Folkmann 1984) postulates that when aspects of a threat, such as an earthquake, are perceived to be uncontrollable, a threatened individual is more likely to cope with threat by denying its existence rather than by taking action to reduce the risk of harm.

Research has shown that people often make biased appraisals of their own risks and prospects relative to other persons. This bias is usually optimistic, meaning people see themselves as less likely to be harmed by future risks than others (Helweg-Larsen 1999). Further research found that participants judged they were less likely to suffer harm in a major earthquake than acquaintances in their peer group, however the same participants judged that their own property was more likely than others' to be damaged in an earthquake (Spittal et al. 2005).

A study in Christchurch and the wider Canterbury region (Becker 2010) displayed this optimistic bias in preparedness for a major earthquake. It showed that respondents considered they were halfway between being *very prepared* (Likert scale value 5) and *not at all prepared* (Likert scale value 1), with respondents in the wider Canterbury region (Mean value 3.3) being more prepared than those living in the city (Mean value 2.7).

Following the trend from (Becker 2010), although they were not explicitly asked, the population in this study is assumed to have been previously exposed to preparedness information through various sources (e.g., from (Becker 2010), television [82%],yellow pages in the telephone book [78%], newspapers/magazines [72%], and other written brochures [69%]). The New Zealand Earthquake Commission (EQC) have broadcast their *Get Ready Get Thru* message regularly on TV in New Zealand, have dropped pamphlets and brochures to households, and has a web site available for information (MCDEM 2011a). The telephone directory also has a dedicated section to guide people in the event of an emergency. Viewers and readers have the opportunity to be educated on the basic plans and supplies they should have for the first three days after a disaster, a period for which experts believe the populace will need to be self-sufficient. In schools, *What's the Plan Stan* (Kia Takatū is the Māori version) is a resource for teachers to help them develop students' knowledge and skills to prepare for, and safely respond to, disasters (EQC 2012). It also encourages students to take this information home to their families to help them get ready, too.

Figure 1-7 : What's the Plan Stan? – Kia Takatū

1.5.9 Preparing to recover

Disaster preparedness includes actions taken in advance of disasters to deal with anticipated problems of emergency response *and* disaster recovery. Of particular importance to disaster recovery preparedness, hazard insurance is designed to provide financial protection from economic losses caused by disaster events, the purchasing costs of which are based on actuarial risk. Whereas money cannot mitigate disaster, it does enable

choice in the response. It can also lower the overall cost of protection by encouraging risk prevention measures. The insurance industry will pay an estimated 80% of the overall cost of the February 2011 Christchurch Earthquake in New Zealand, but no more than 17% for the disastrous event in Japan in March 2011. Earthquake insurance penetration, in fact, is highest in New Zealand, and is very low in Japan, particularly for commercial properties (Bevere & Grollimund 2012) – refer to Table 1-1.

In New Zealand, the Earthquake Commission (EQC) underwrites the first NZD 20'000 + GST for contents and NZD 100'000 + GST for dwellings of an insurance claim arising from a disaster event: the contents and property must be privately insured in order for it to be covered by EQC (Earthquake Commission (EQC) 2011). Bare land and houses that are in the process of being built are not insured by EQC.

Table 1-1 : Recent major earthquake events and associated economic losses (Bevere & Grollimund 2012)

Date	Country	Economic losses, USD bn	Economic losses as % of GDP	Insured losses, USD bn	Insurance industry contribution
11.03.2011	Japan	210 to 300	3.8% to 5.4%	35	12% to 17%
27.02.2010	Chile	30	18.60%	8	27%
22.02.2011	New Zealand	15	10.00%	12	80%
12.01.2010	Haiti	8	121%	0.1	1%
04.09.2010	New Zealand	6	5.30%	5	81%
06.04.2009	Italy	4	0.20%	0.5	14%
23.10.2011	Turkey	0.75	0.10%	0.03	4%
04.04.2010	Mexico	0.95	0.09%	0.2	21%

Not everyone can afford house insurance. Tenants are not usually insured for alternative accommodation, unlike an owner-occupier, should the house they are occupying needs to be vacated and repaired. This can increase the vulnerability of the under-insured or not-insurable.

1.5.10 Evacuation

Evacuation may be a response to a forewarned disaster that can be practised (tsunami evacuation), planned for (e.g. a hurricane), agency-lead (e.g. response to rock fall danger, wild fire, or encroaching flood waters), or self-evacuation (such as after an earthquake) when the individuals evacuate by themselves without external assistance.

In the case of earthquakes, one of the few natural hazards that have little or no available warning time, decisions to evacuate will typically be made after the onset of the event and mostly after the shaking of the main earthquake has stopped. The threat of aftershocks will provide pre-warning of possible further events (Mileti & O'Brien 1989).

Evacuation can be mandatory (ordered by authorities and backed by statutory powers), or voluntary (advised but not regulatory or via self-evacuation where the evacuee decides without an advisory to leave).

The process of evacuation may be organised and coordinated by authorities or largely the outcome of self-evacuation; in either case, there will nearly always be some evacuees who will require assistance to evacuate (e.g. transport, mobility aid, resources) (Wright & Johnston 2010).

A part of being prepared for a disaster is a plan to evacuate from the affected area, if required. It could be part of the plans a household has made independently, or plans lain out by a community. Evacuation of the population may be part of a comprehensive Emergency Management plan by the emergency management authorities, which covers all phases of a disaster, from beginning to end. Unforeseen events mean evacuations cannot always be planned for and so evolve as they progress.

Evacuation is advised when the damage or consequences of staying are deemed to pose a life safety risk to those impacted and evacuation is expected to pose a reduced risk. In all circumstances, it is the movement of the population away from immediate danger to a less-dangerous place. An evacuee may have time to prepare or may have to leave immediately. An evacuation may be temporary or permanent.

Evacuation, whether for a few hours, a few days, or permanently, is a factor in social vulnerability, as subpopulations are separated. A post event factor that contributed to

delayed evacuation following Hurricane Katrina was the loss of access to livelihoods. Businesses were physically disrupted due to building damage, employees and owners were evacuated, potential customers were evacuated, or the reason the business existed was erased (Campanella 2006). For those contemplating evacuation, even if unemployed, seeking employment out of the region may not be possible, so how strong a factor loss of livelihood will be as an evacuation decision contributor will be difficult to calculate.

1.5.10.1 Evacuation decision framework

An evacuation and decision needs framework (Figure 1-8) has been developed for Wellington, based on a Californian model (Chang et al. 2009). Because transport out of Wellington is expected to be severely hampered by a major event in the region, many of those that choose or are forced to evacuate their homes will require public shelter within the damaged area. A model framework for calculating evacuation numbers and sheltering requirements is proposed based on a variety of damage and non-damage related factors that contribute to evacuation decision making (Wright & Johnston 2010). The resident population of the Lyttelton study area also faced similar issues to Wellington due to restricted egress routes, and so public shelter would need to be established within the area.

Multiple factors that contribute to household evacuation decision-making have been included to recognise that post-earthquake evacuation decisions are based not only on damage states of buildings or loss of lifeline utility services, although they contribute to the process (Wright & Johnston 2010). The three decisions leading to evacuation in the model concern:

- The structural safety of the building
- The functional soundness of the building
- Neighbourhood liveability

Each of these decisions is discussed further, below.

Once a decision has been made to self-evacuate, a final decision must be made to where.

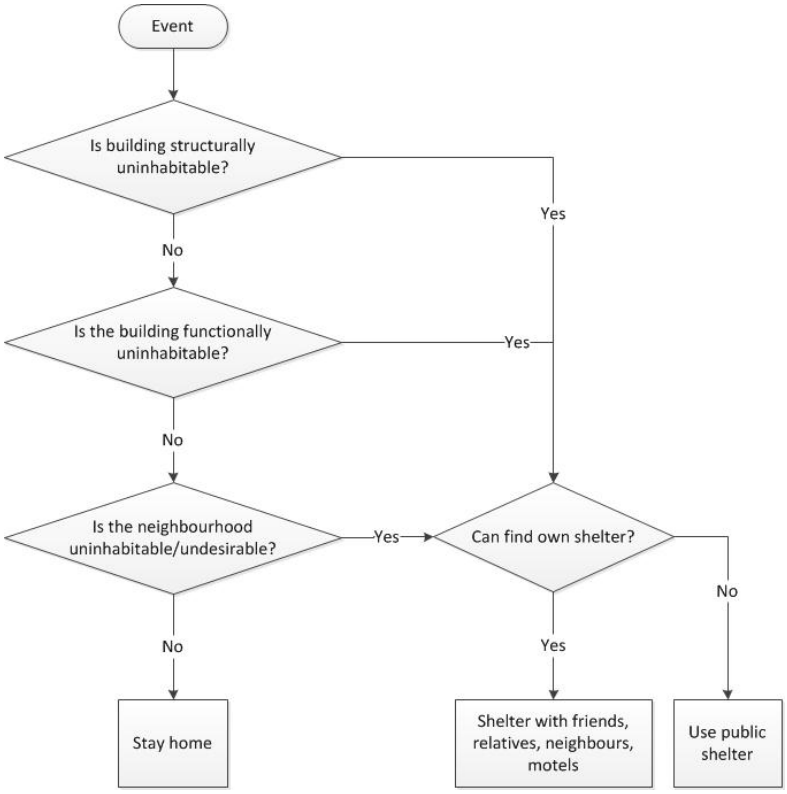


Figure 1-8 : Framework of the evacuation and sheltering needs decision tree based on Chang et al 2009 (Wright & Johnston 2010)

1.5.10.1.1 Building structural safety

New Zealand has adapted the US building safety evaluation process: red (unsafe); yellow (restricted use); green (safe to use) in the 1990's (NZSEE 2008). It was used for the first time in New Zealand after the 2007 Gisborne Earthquake (Brunsdon 2009). The same process was used after the main and major aftershocks in 2010 and 2011 by CDEM, in and around Christchurch, during the State of Emergency.

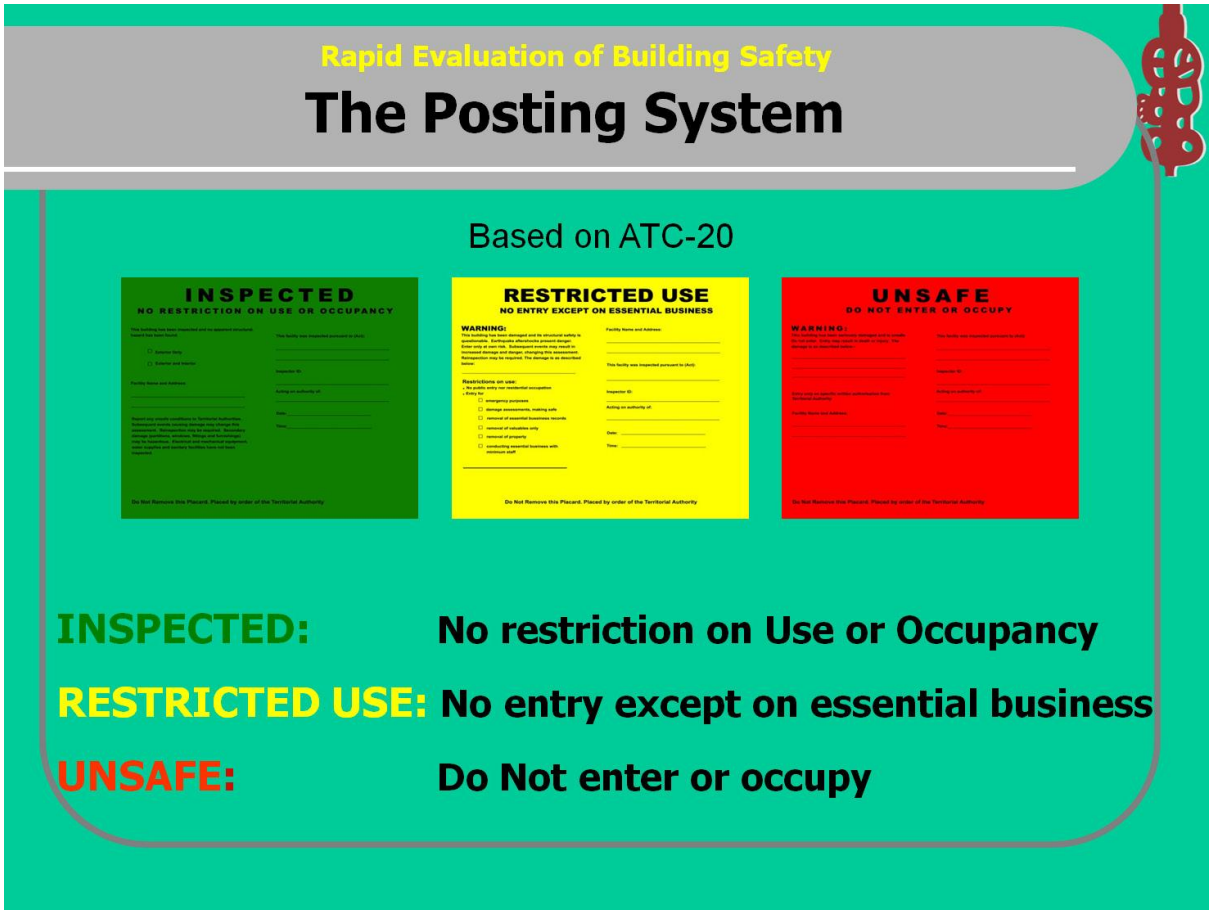


Figure 1-9 : Red, Yellow, and Green Stickers (Brunsdon 2009; NZSEE 2008)

Once the State of Emergency under which the stickers are applied is ended, the Building Act 2004 (New Zealand Government 2004a) applies, and it is this act which governs the structural soundness of the building. In the case of Christchurch, CERA (the Canterbury Earthquake Recovery Authority) operates under the Canterbury Earthquake Recovery Act 2011 (New Zealand Government 2011), and has the powers to demolish or require immediate rectification of building faults. The Christchurch City Council has the power to issue a 'notice to fix' under the Buildings Act 2004. A notice to fix is a statutory notice requiring a person to remedy a breach of the Building Act 2004 or regulations under that Act. It is similar to a notice to rectify under the Building Act 1991 but, unlike a notice to rectify, a notice to fix can be issued for all breaches of the Act, not just for building work. If such a notice to fix is not complied with, the building can no longer be occupied as it has technically not been issued a building consent authority/code compliance certificate, which forces owners to immediately vacate their property or face fines of up to NZD 200'000 plus NZD 20'000 / (part)day thereafter, in accordance with Section 168 of the Building Act 2004,

and associated court appearances. Notices to Fix have been re-issued to 27 homes in the Christchurch Port Hills area that are still occupied (Canterbury Earthquake Recovery Authority 2011), although not all of these are within the study area. For the most part, the notices have been issued because of on-going threat of rock fall, cliff collapse, or land slide. The majority of those residents still occupying their properties do not see the same risk potential as the CCC, and so are protesting the council decision by remaining (Greenhill 2012). Two notices to fix were withdrawn after the affected Lyttelton residents made safe their property by securing or breaking apart threatening boulders above their property (Young 2012).

The damage after the recent Canterbury earthquakes was widespread to the degree that building damage classification systems were initially and in the medium-term overwhelmed. For the most severe damage it would have been obvious whether a residence is inhabitable or not due to structural integrity failure such as roof collapse, movement on foundations, or walls failing. Where professionals are unavailable to classify building damage, residents were left to decide themselves whether it was safe to remain in their home based on their own knowledge of building design and construction. How residents determined what was structural (dangerous) and what was cosmetic (relatively safe) damage is unknown.

A further issue is that of the surrounding structures: neighbouring buildings; retaining walls; areas in rockfall- and mass movement-prone areas. Given that many residents were concentrating on their own property meant that they were unaware (until advised by a professional assessor or neighbour) of potential danger to themselves and to their property.

Even after having their residence yellow or red stickered, people still tended to use at least a part of their property if they were not concerned of the potential risk.

1.5.10.1.2 Building functionally sound

Whether utilities continue to function affects a person's ability to continue habitation in their residence (e.g. prepare meals, drink uncontaminated water, keep warm, wash utensils and clothes, bathe, receive messages via electronic media, or communicate with others) (Bourque et al. 1992). Inability to perform these basic activities often motivates people to evacuate their homes after a disaster (Bolin & Stanford 1991).

Case studies of disaster-struck communities (Nigg 1990; Tierney 1991) illuminate the advantages and disadvantages of functionally interconnected utility and lifeline failures. Among the drawbacks, for example, is that power failure often impacts the functioning of water, sewage, and communication systems. Work undertaken by the Canterbury Engineering Lifelines Group (Gordon 2009) concerning lifeline interdependencies has highlighted cascading failures should the electrical utility be lost (Figure 1-11, below).

Widespread loss of water supply is not a common occurrence in Lyttelton, or New Zealand in general, and could pose severe problems for many households. This study suggests more than 75% of households have a contingency supply of water (the recommended amount is 3 litres per day per person for three days). Loss of waste water utility (either at the treatment centre or destruction of pipes) can be offset by having people dig their own long-drop in their garden or by the adequate distribution of Portaloos or chemical toilets to affected neighbourhoods.

Figure 1-10 : Clockwise from top left - His Worship the Mayor of Christchurch, Bob Parker, demonstrating how to operate a chemical toilet at a press conference (Heather 2011), delivery of Portaloos to Lyttelton (CERA 2011), a decorated back-garden long-drop (McLean 2011)

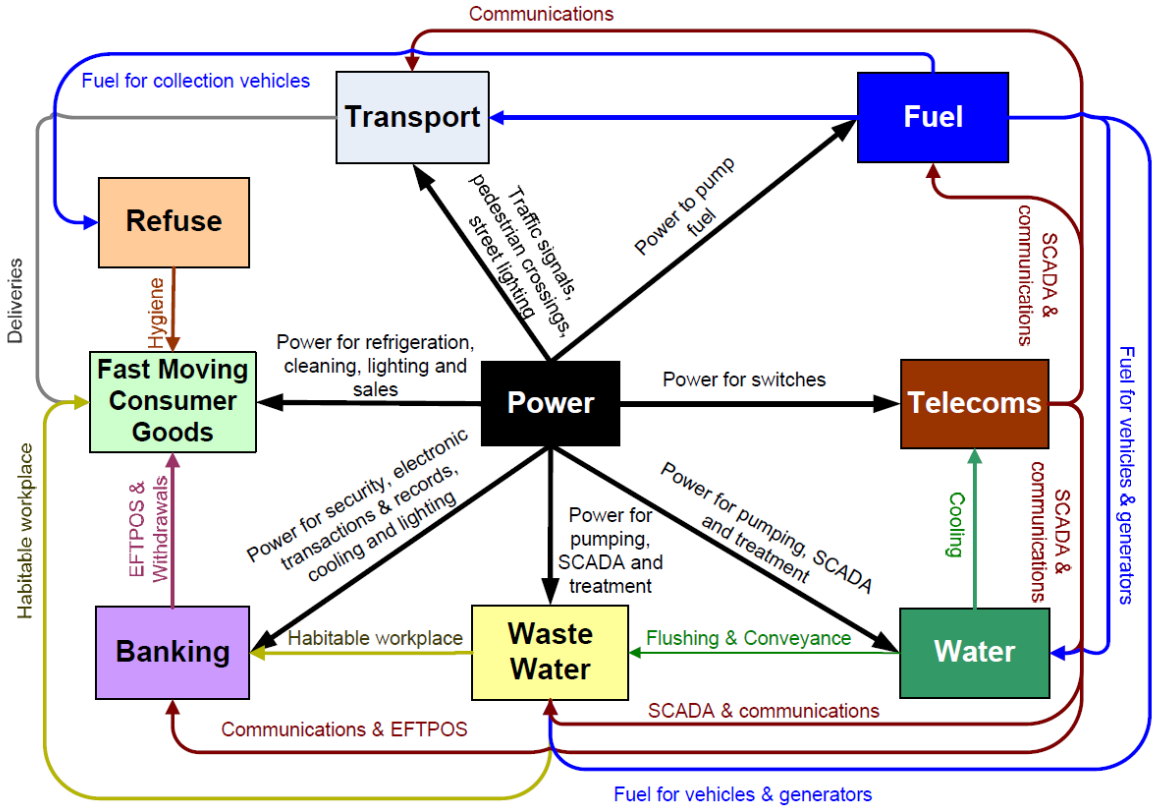


Figure 1-11 : Cascading Impacts of Power Failure (Gordon 2009)

1.5.10.1.3 Household liveability

Factors that are not structural- or lifeline-related, that are recognised as part of the decision making process for individuals or households, often involve the functional needs of the household members (e.g. mobility, income, dependencies) (Vogt & Sorenson 1992). Factors that make it more likely for a household to evacuate are: access to a vehicle; access to resources for travel (money, fuel); a household that includes dependant children (except sole parent/caregiver households); a household where members have somewhere accessible to evacuate to (Bourque et al. 1973; Bourque et al. 1992; Chang et al. 2009). Factors likely to make sheltering at home more likely include: whether the household is a sole-parent or sole-caregiver home; whether members of the household have mobility or health issues (medication, support equipment requirements); whether the house is rented; whether the house is close to the earthquake epicentre; and whether the household is experiencing (or members have a fear of) aftershocks. Because these factors vary from household to household, identification of households more or less likely to evacuate is problematic.

1.5.10.1.4 Neighbourhood liveability

Evacuation decision-making not related to structural damage is based upon neighbourhood liveability, as well as household liveability. Neighbourhood liveability is determined by the support systems and services required for household wellbeing and function. The longer recovery takes, the more difficult it becomes for households to remain in their homes when these systems and services are removed (Wright & Johnston 2010).

Transport is required by many households to allow them to meet their everyday needs for social and retail contact (visiting friends and family, purchasing household supplies, seeking medical attention, travelling to and from work or school, etc.). Transport, whether public or private, requires passable roads.

Community groups are focal to maintaining cohesion and social networks. The various church congregations help each other in times of need. The Lyttelton Timebank initiative and Project Lyttelton help the general community in Lyttelton. The marae at Rapaki is a crucial meeting and communal gathering place for Maori. London Street is the business, retail, and social heart of Lyttelton.

In the communities based within the study area, cultural- and ethnic-based groups (such as Maori communities centred on the marae in Rapaki), church groups of all denominations, common interest groups (such as the Lyttelton Timebank and Project Lyttelton), and recreational clubs (such as the Rugby Football Club and marina) provide essential services to residents. Where these groups and clubs are disbanded due to hazard events, individuals and households can feel isolated or unsupported. The loss of social support networks can increase the stress of the event, and can contribute to the desire to relocate. Where social support networks continue to function, sheltering in place is likely to be viewed more favourably. These networks and groups can often take on new response and recovery roles during and after emergencies, when this process occurs they are termed “emergent groups” (Murphy 2007) and ideally their skills and resources incorporated into civil defence emergency management (CDEM) planning.

Another factor that affects whether residents of a particular neighbourhood will evacuate is whether a mandatory evacuation order is given, and how it is delivered and by whom. As has been researched extensively for many types of disasters, even under a mandatory

evacuation not all residents will leave (Elder et al. 2007; Hauser et al. 2006; Haynes et al. 2010; Heath et al. 2001). When this occurs the decision can be based on individual factors (e.g. don't believe the threat is real, lack of trust in authorities, unable to evacuate due to mobility, etc.) or neighbourhood factors (e.g. local friends and family are choosing not to go, can't evacuate with a pet) (Wright & Johnston 2010).

If authorities supply ill-suited accommodation to evacuate to, residents may rather attempt to find their own (Riad et al. 2001).

1.5.10.2 Emergency Evacuation drills

Emergency evacuation drills, either organised by and for the authorities alone, or for the affected population, is one way authorities from a number of countries have prepared for a disaster. Japan has a yearly drill that involves residents and authorities. California and other West-coast states have an annual shakeout: in 2010, 7.9 million residents took part, including school and university campuses, private businesses, and households (ShakeOut 2011). Similar exercises with popular participation have been carried out in New Zealand (Earthquake Country Alliance). Most other exercises in New Zealand have concentrated on the CDEM and associated services response, based on a simulation of communication traffic and a few physical exercises in the field, but with little involvement of the general population due to the perceived social and economic cost (MCDEM 2011b,2012).

1.5.10.3 Pre-evacuation journeys

A phenomenon observed before warned events, such as hurricanes or far-field tsunami, is the behaviour of individuals prior to evacuation as they make trips (Murray-Tuite & Mahmassani 2007) or otherwise delay their evacuation journey, or make detours en-route during evacuation, to do business, check on neighbours, purchase provisions, etc. (Noltenius 2008). Such behaviour affects evacuation models and can cause congestion on parts of the road system that are temporarily adapted to single-flow traffic to aid evacuation.

1.5.10.4 Evacuation decision making

Research into evacuation decision making has largely been focussed on those hazards for which warnings are provided, examining how people receive and interpret warnings, and whether they choose to evacuate or not (Fischer III et al. 1995). A large body of research

into hurricane and tsunami evacuation behaviour exists in the international literature, but there have been limited studies into the post-event evacuation process that follow earthquake events (Bourque et al. 1973; Bourque et al. 1992). Reports from the Loma Prieta earthquake of 1989 (Bourque et al. 1992; Tierney 1994) found that overall 22 per cent of respondents in their survey reported having evacuated from their homes for at least some period of time. Official shelter use was at a peak of 2'500 displaced persons nightly, about 20% of the estimated 12'000 to 13'000 left homeless (Bolin & Stanford 1991). By the end of the third week after the earthquake, all but 500 of those displaced were either relocated into temporary housing or were back in their homes. Most residents in the sample that evacuated returned to their homes within 24 hours.

The model proposed by (Chang et al. 2009; Wright & Johnston 2010) is perhaps too simplistic, as other factors affecting the process of evacuation, and therefore the decision to evacuate, are not addressed: these include access to transportation, mobility, caring for dependents (including animals), and children. Indeed, (Heath et al. 2001) showed that households with children responded more readily to evacuation than those with pets.

Studies of actual and modelled events in the United States suggest that post-earthquake evacuation decision making is complex, and not solely explained by building structural safety or loss of lifeline utility factors (Wright & Johnston 2010).

1.5.10.5 Children

(Heath et al. 2001) report that households with children have a lower threshold to evacuation than those without. Evacuation of children must, however, be done in a safe and secure environment so as not to increase the potential for post-traumatic stress disorder (PTSD) (Smith et al. 2005). Unfortunately, one of the symptoms of PTSD is separation angst, something which must be guarded against in an evacuation by emergency services.

It should be important not to subject children to over-stressed adults, especially their parents and the caregivers they turn to for security. "*Many children experience their parents screaming, crying and being out of control as never before*" (Shelby & Tredinnick 1995). It has been found that positive adult attitudes facilitate a child's ability to deal with trauma (Davidhizar & Shearer 2002).

A quick return to normalcy is critical for the child's mental wellbeing. It is important for schools to be opened as quickly as possible: they are at the heart of the child's life and community. If a child is at school when a disaster occurs, to avoid mental stress on the child, it is imperative that the school and the child's parents and caregivers have communicated beforehand on the procedure to be followed. It is the responsibility of schools and families to prepare for an emergency, but they often have little or no experience of hazards, and any knowledge they do have is often of minor events (Johnston et al. 2010).

1.5.10.6Animals

Those with pets have a higher threshold to evacuation than those without (Heath et al. 2001). In a recent survey (Glassey 2010a), 79% of respondents strongly agreed and 20% agreed that pets were family members. Impediments to evacuation with animals are also the ability to take companion animals (Glassey & Wilson 2011) or pets (Glassey 2010a) into emergency shelters, owning multiple pets (too many to transport at one time), owning outdoor dogs, or not having a cage or transport (Glassey 2010b). A further dimension is owners not prepared to evacuate if their cats have gone missing during an earthquake (Press 2010). Pre-disaster planning should place a higher priority on facilitating pet evacuation, as 56% of respondents in a recent survey (Glassey 2010a) agreed or strongly agreed that they would not evacuate if told to do so unless they could take their pets with them.

Additionally, some owners may no longer be able to cope with their pets and have to simply abandon them (Stylianou 2011). New Zealand's animal welfare legislation, the Animal Welfare Act 1999 (New Zealand Government 1999), requires owners of animals, and persons in charge of animals, to take all reasonable steps to ensure that the physical health, and behavioural needs of the animals are met.

Physical health and behavioural needs are defined in the Act as what are generally referred to as the Five Freedoms (WSPA 2012):

- Proper and sufficient food and water
- Adequate shelter
- Opportunity to display normal patterns of behaviour

- Physical handling in a manner which minimises the likelihood of unreasonable or unnecessary pain and distress
- Protection from and rapid diagnosis of any significant injury or illness

In a disaster, these 'Five Freedoms' are at risk and must still be met. The Animal Welfare Act therefore remains in force and the owner or carer is legally responsible for the animals in a disaster (WSPA 2012).

The importance of specific animal welfare emergency management legislation has not been realised in New Zealand, in contrast to the passage of the Pet Emergency Transportation and Standards (PETS) Act 2006 by US lawmakers to address major lessons learned following Hurricane Katrina (Glassey 2010b; Glassey & Wilson 2011). The PETS Act 2006 required local and state emergency management plans to include arrangements for pets and service (disability assistance) animals; funding for state and local pet and service animal emergency preparedness; and lastly, requirements that pets were rescued, cared and sheltered during emergencies (Edmonds & Cutter 2008).

The Civil Defence Emergency Management Act 2002 however is not so clear in its application to animal welfare during a state of emergency. Under Section 86, powers to evacuate may only be executed for the preservation of human life, and such evacuations only provide for the exclusion of persons or vehicles – not animals (Glassey & Wilson 2011).

1.5.10.7Speed of evacuation

When agency-lead evacuation is required for a rapid-onset disaster, easily digested situational awareness information should be available to the population, and time provided to organise themselves. (Busby 2010) noted that one consequence of rapid evacuation during the Eastern Bay of Plenty, New Zealand, flood event was that emergency service personnel operated with such a sense of urgency that this heightened the level of shock and cognitive disruption for the evacuees, which in turn exaggerated the trauma and impeded individual recovery (Gordon 2008). Pre-event training and information dissemination can alleviate some of this angst and help the community respond and recover more quickly.

1.5.11 Flight

Movement away from immediate danger to a place perceived to be less dangerous can be defined as *flight* if an unplanned reflex action, but the place of perceived less danger may actually be more dangerous. For example, the flight response may have contributed many deaths in the Christchurch CBD during the Christchurch Earthquake due to people immediately vacating buildings during the initial shaking and consequently being buried under collapsing façades, rather than sheltering under furniture in the building before proceeding out in a more orderly fashion once the shaking had subsided.

Sometimes flight towards danger is altruistic in nature, to seek out loved ones, to help those in need, or to recover property.

2 Natural and manmade hazards

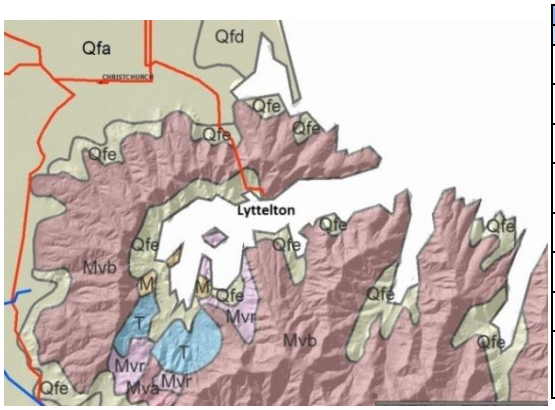
2.1 Hazard Inventory

Hazards can be divided into natural and man-made, and classified as to the veracity of their process: rapid-onset, warned, slow-onset (Table 2-1).

Table 2-1 : Hazards

	Rapid-onset	Warned	Slow-onset
Natural			
• Earthquake	✓		
• Rockfall and landslide	✓	✓	✓
• Tsunami	✓	✓	
• Loess-colluvial gully tunnelling		✓	✓
• Flooding	✓		
• Storm (including hurricane and tornado)	(✓)	✓	
• Snowstorm		✓	
• Fire	✓	✓	
• Drought			✓
• Pandemic			✓
Man-made			
• Explosion	✓		
• Chemical spill	✓	✓	
• Noxious vapours	✓	✓	
• Terrorism	✓	✓	

2.2 Geological setting of study area



Legend				
Code	Lithography	Age	Era/Period	Simple unit
Qfa	Postglacial alluvium	Late Quaternary	Quaternary	Quaternary sediments
Qfd	Dune sand	Late Quaternary	Quaternary	Quaternary sediments
Qfe	Extensive thick loess	Late Quaternary	Quaternary	Quaternary sediments
M	Mainly sandstone and siltstone (locally alternating and graded); local limestone	Miocene	Tertiary	Tertiary sediments
Mva	Andesite	Miocene	Tertiary	Tertiary volcanics
Mvb	Basalt, tuff (basal flows possibly Miocene)	Miocene	Tertiary	Tertiary volcanics
Mvr	Flow rhyolite, breccia, obsidian	Miocene	Tertiary	Tertiary volcanics
T	Interbedded greywacke and argillite (greywacke graded in places); minor basaltic and spilitic volcanics, chert; rare limestone lenses	Triassic	Mesozoic	Triassic sediments

Figure 2-1 : Geological setting of study area

Lyttelton lies within the highly eroded caldera of the Lyttelton volcano (11.0 – 9.7 Ma) (Hampton & Cole 2009).

The study area is surrounded by highly jointed basaltic lava flows, which are interbedded with loessal and colluvial-loessal deposits (Bell & Trangmar 1987). The loessal and colluvial-loessal deposits have been the cause of erosion over the past 150+ years of development on the Port Hills (Yetton 1986), including the creation of rills and tunnelling, and have thus been the focus of engineering geology investigations.

The Lyttelton Port wharves are mostly built on reclaimed land. The area used for the sport field and marina are also built on reclaimed land.

2.2.1 Tectonic setting of New Zealand/Canterbury

New Zealand lies on the boundary of the Pacific and the Australian plates and its active tectonics are dominated by three main features (Figure 2-2). Beneath the North Island and northern South Island the Pacific plate is subducting obliquely beneath the Australian plate at the Hikurangi trough. In contrast, in the Fiordland region in the southwest of the South Island subduction is reversed, with the Australian plate subducting obliquely beneath the Pacific plate at the Puysegur trench. Between these two subduction zones the plate boundary is characterized by continental convergence (Gledhill et al. 2011).

In the central South Island, the velocity of the Pacific plate relative to the Australian plate is 38 mm/yr at an azimuth of 248° (DeMets et al. 2010). The Alpine fault accommodates at

least 70–75% of this relative plate motion. Paleoseismic studies indicate 27 ± 5 mm/yr of strike-slip and 5–10 mm/yr of dip-slip motion on the Alpine fault (Norris & Cooper 2001).

Figure 2-2 : Tectonic setting of New Zealand (GNS Science 2011b)

The dip-slip component of motion is largely responsible for the uplift of the Southern Alps. A balancing of the plate motion budget across the central South Island using GPS, seismological, and geological data suggests that up to 5 mm/yr of active deformation is possible on faults distributed within the Southern Alps and up to 100 km to the east of the Alpine fault (Wallace et al. 2007).

Seismicity in the South Island is nearly all confined to the crust (Figure 2-3) with the exception of a small number of 40 – 100 km deep earthquakes beneath the Southern Alps (Figure 2-4). Deeper events are confined to the subduction zone to the south of the Alpine Fault near Fiordland (Puysegur Trench) and to the north around the Marlborough Sounds.

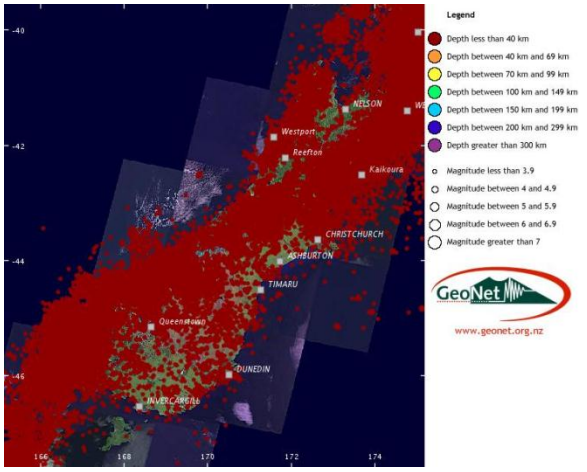


Figure 2-3 : Shallow (0 - 40km) seismic activity in the South Island, New Zealand (1990-2009)

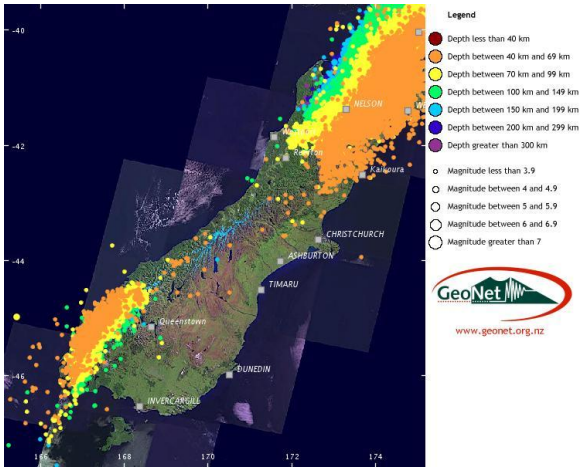


Figure 2-4 : Deeper (>40km) seismic activity in the South Island, New Zealand (1990-2009)

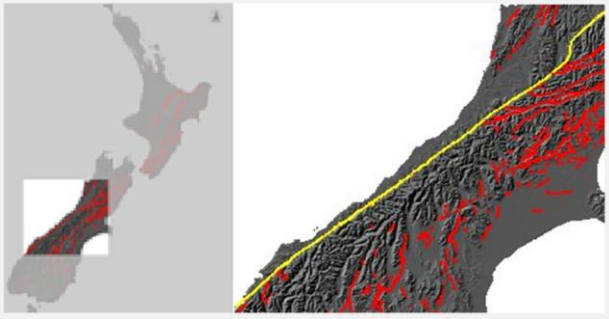
2.3 Earthquake

2.3.1.1 Alpine Fault

The plate boundary at the surface is marked by the Alpine fault, a 650-km-long (850 km inclusive of the offshore section), right-lateral strike-slip fault that has had 460 - 480 km of displacement since the Late Oligocene-Early Miocene (Yetton 2000). Paleoseismic evidence suggests that the Alpine fault ruptures in major earthquakes (M_w > 7.5) with recurrence intervals of ~200–300 years, with the most recent event in 1717 (Rhoades & Van Dissen 2003).

Table 2-2 : Alpine Fault

Alpine Fault	
Fault sense	Dextral
Recurrence interval	< 2000 years
Last event	Last Millennium
Slip rate	High
Single event displacement	Major



Based on Californian, Japanese, and Turkish examples, seismological evolution takes place as the fault plane is smoothed by successive offsets (Stirling et al. 1996). As a result of this structural and seismic evolution the size of major earthquakes increases and the relative frequency of intervening smaller earthquakes decreases (Yetton 2000).

(Adams 1980) suggests that the anomalously low levels of recorded seismicity along the Alpine Fault points to a "seismic gap" where comparable sections of the plate boundary have had large earthquakes predicted after relatively low recorded seismicity (Sykes 1971) (Rong et al. 2003). Current analysis shows 69%-89% of the Australian-Pacific plate motion is accommodated by the major faults (Alpine-Hope-Kakapo) in the transitional area between Hokitika and Inchbonnie, and the 50% drop in slip rate on the Alpine fault is taken up by the Hope and Kakapo faults at the southwestern edge of the Marlborough Fault System (Langridge et al. 2010).

The paleoseismic history can be used in conjunction with typical recurrence data from other plate boundary faults to predict the probability of the next earthquake using the method of (Nishenko & Buland 1987). This indicates a probability over the next 50 years of an Alpine Fault rupture as 65 ± 15%, increasing to 85 ± 10% over the next 100 years (Yetton et al. 1998). A later study (Rhoades & Van Dissen 2003), which takes into consideration many of the uncertainties, indicates the 20-year hazard under the lognormal model (18%) is about double the long-term average rate but less than half of that estimated in previous studies (Table 2-3).

Table 2-3 : Comparison of estimated probability of rupture of the central Alpine Fault using different methods

	Time interval			
Model	**1 year**	**20 year**	**50 year**	**100 year**
Lognormal (Rhoades & Van Dissen 2003)	1%	18%	38%	60%
(Yetton et al. 1998) after (Nishenko & Buland 1987)			65 ± 15%	85 ± 10%

2.3.1.2 Nearby Active Faults

(Elder et al. 1991) discussed the active faults within 200 km of Christchurch as likely having the most severe consequences in a future earthquake. These faults include the Porters Pass

Fault, Ashley Fault, and Hope Fault. (Pettinga et al. 2001a) continues this work to provide the foundation for the probabilistic, seismic hazard assessment (PSHA) for the Canterbury region. The PHSA is further qualified in (Stirling et al. 2001), that suggests a 1'000-year return period for 0.2 g PGA 1-second period shaking, increasing to 1.3 g PGA 0.2-second period shaking in the Canterbury region. Both reports have presumed the presence of unknown faults (prior to the Darfield Earthquake) but have found little direct evidence in the geological record.

Table 2-4 : Hope Fault

Hope Fault	
Fault sense	Dextral
Recurrence interval	< 2000 years
Last event	Historical
Slip rate	High
Single event displacement	Major

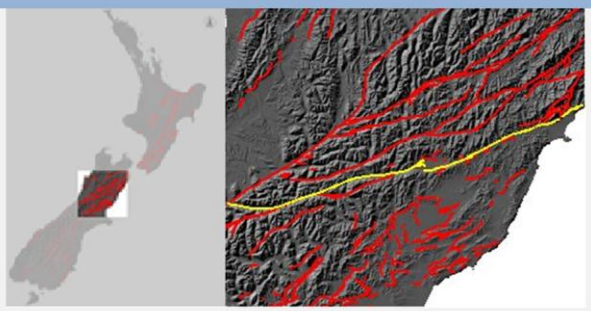


Table 2-5 : Porters Pass Fault

Porters Pass Fault	
Fault sense	Dextral
Recurrence interval	< 2000 years
Last event	Historical
Slip rate	Medium
Single event displacement	Major

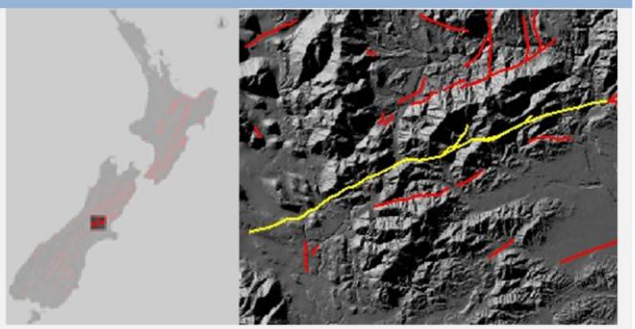
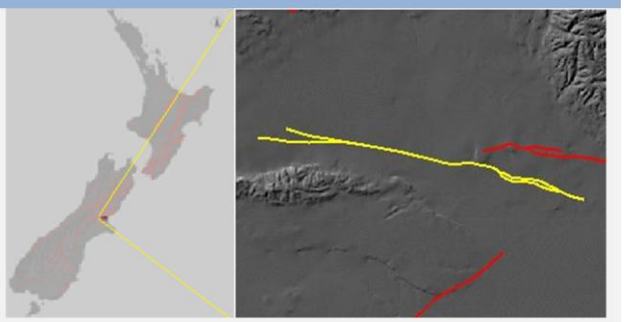


Table 2-6 : Ashley Fault

Ashley Fault		
Fault sense	Reverse	
Recurrence interval	2000 - 3500 years	
Last event	Not established	
Slip rate	Not established	
Single event displacement	Not established	

The little-studied Canterbury Plain Seismicity Zone (CPSZ) has been the focus of a large number of shallow epicentres since 1942, and their location away from known active faults and their proximity to Christchurch means they are particularly important for determining seismic hazard in Christchurch.

The epicentre of the most damaging historical Christchurch Earthquake prior to 2010, the M_w 5.7 (MM VII – VIII) 5th June 1869 New Brighton Earthquake (Pettinga et al. 2001b), lies just within this zone, and borders the Pegasus Bay Seismicity Zone (PBSZ).

2.3.2 Effects of historical earthquakes

The 31st August 1870 Lake Ellesmere Earthquake (estimated M_w 5.6 – 5.8) strongly shook Lyttelton with rocks falling from cliffs around Lyttelton Harbour (Webb et al. 2011).

The 5th December 1881 Castle Hill Earthquake (Mw 6.0) (Pettinga et al. 2001b), centred on the Castle Hill Basin, damaged buildings in Christchurch, including the spire of the Christ Church Cathedral, and broke windows and felled chimneys (NHRP 2011).

The 1st September 1888 M_w 7.0 – 7.3 North Canterbury (Amuri) Earthquake on the Hope Fault, which caused the top 8 metres of the Christ Church Cathedral stone spire to collapse, also caused minor rock falls around Lyttelton Harbour (Webb et al. 2011).

2.3.3 Possible effects of a large earthquake from the Southern Alpine fault, Hope fault, etc

(Yetton 2000) argues that the recurrence behaviour of the Alpine Fault will resemble other plate boundaries around the world, so the little evidence available for ruptures along the Alpine Fault can be further extrapolated.

When applied to the Alpine Fault, this method of using similarities produces a much higher probability estimate of rupture when compared with (Elder et al. 1991): a 50-year probability of rupture of 65 % (range 50 – 80 %) and a 100-year probability of rupture of 90 % (range 80 – 95 %).

Recent modelling of attenuation for Christchurch have revised the severity of previous prediction down to a likely MM VII, with MM VIII extremes in locations of amplification caused by underlying soft sediment, as predicted by (Elder et al. 1991). The likely long period and duration of the earthquake shaking (upwards of 2 minutes) will increase the likelihood of liquefaction (Yetton 2000), with taller buildings subject to short-period acceleration.

The increased duration of shaking will probably lead to an increase in the liquefaction effects and ground cracking at the hazardous goods wharf and Lyttelton Port over that experienced in the Darfield Earthquake and similar to that of the Christchurch and Sumner Earthquakes of February and June 2011, as affected soils will have a greater opportunity to mobilise.

Prolonged shaking will have a negative affect on structures and infrastructure.

2.3.4 Effects of the M_w 7.1 Darfield Earthquake (September 2010)

2.3.4.1 Canterbury Earthquake Sequence

At 04:35 on Saturday 4 September 2010 local time, the moment magnitude (M_w) 7.1 Darfield Earthquake struck approximately 10 km southeast of the town of Darfield and within 40 km of New Zealand's second largest city, Christchurch, causing extensive damage in the city and surrounding region. There was no loss of life due to a fortunate combination of strict building codes and the earthquake occurring at 04:35 local time when the streets

were largely empty, but about 100 people were injured (two seriously) and many more were made homeless, at least temporarily. Regional planning had been undertaken to reduce critical infrastructure and lifelines vulnerability to natural hazards in 1997 (Lamb et al. 1997).

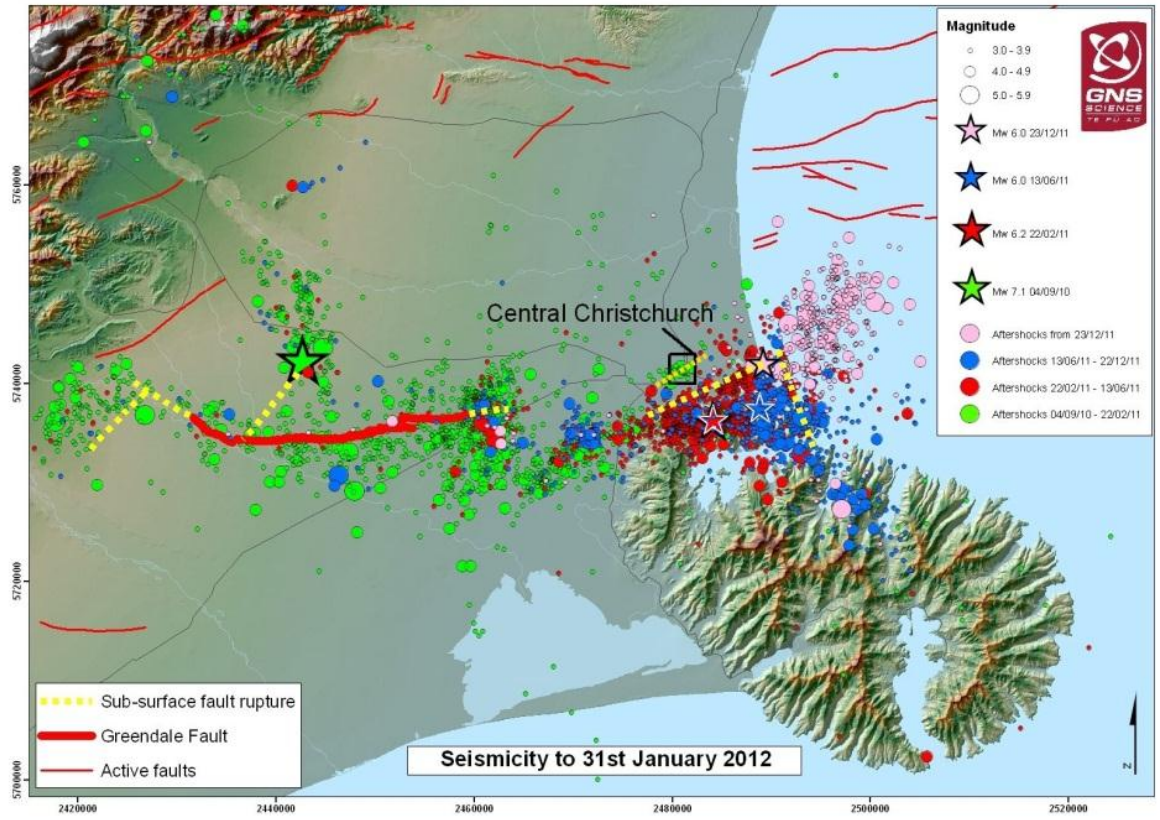
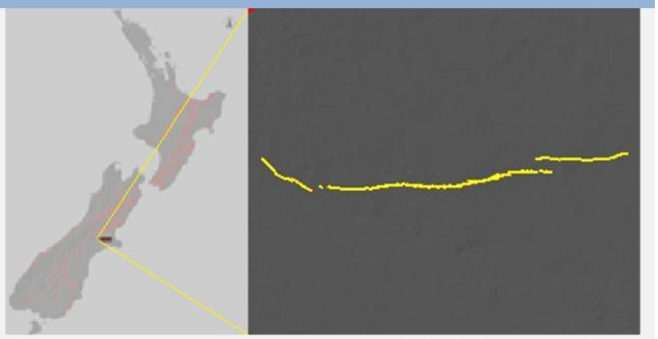


Figure 2-5 : Seismicity 4th September 2010 to 31st January 2012, surrounding Christchurch, New Zealand (from GNS Science)

2.3.4.2 Greendale Fault

The importance of the Canterbury Plains Seismic Zone was recognised on the morning of 4th September 2010 when the Greendale Fault (and possibly two or three others in sympathy (Gledhill et al. 2011)) ruptured, causing the M_w 7.1 Darfield Earthquake and subsequent aftershock sequence.

Table 2-7 : Greendale Fault

Greendale Fault		
Fault sense	Dextral	
Recurrence interval	10’000 – 20’000 years	
Last event	Historical	
Slip rate	Low	
Single event displacement	Major	

The Darfield Earthquake, although not devastating, caused major disruption to Christchurch and surrounding areas.

Lyttelton Port was affected by liquefaction of the wharf area and there were failures of the spans between wharves and the docks. The tunnel and railway lines out to Rolleston suffered damage, so that goods trains were not able to run. The earthquake also caused widespread liquefaction in the dangerous goods terminal under the berms surrounding the fuel tanks (Figure 2-9).

The building stock of Lyttelton, consisting of many older properties, some dating back to the Port Cooper era, suffered from collapsed chimneys and brick frontages. Major unreinforced stone buildings suffered some light damage.

The Lyttelton Road Tunnel was closed for inspection and maintenance. The anticipated slips at the portals (Lamb et al. 1997) did not eventuate, however the canopy was judged to be subject to failure, leading to an inspection.

A large portion of Castle Rock (Figure 2-6, below), situated in close proximity to the Heathcote portal, did fall, resulting in blasting and scaling work and the required temporary closures of the tunnel approach (see Figure 2-18, below).

Figure 2-6 : Rock falls from Castle Rock on to old talus slope. Most are from the 4 Sep 2010 Darfield Earthquake, with some from the 22 February event (GNS Photo-GTH_6017).

The Sumner Road over Evan's Pass was closed whilst scaling, blasting and rock removal work took place. The road was reopened in the beginning of December (stuff.co.nz 2010a), with a speed restriction in place. At the time of road reopening, the retaining wall to the south of the road, protecting traffic from the precipice into Lyttelton Harbour, was still in need of repair in places, with subsidence evident on the road surface.

Within Lyttelton, many scoria retaining walls have slumped or have fallen into or away from roads.

London Street, Lyttelton, was closed to traffic due to building collapses, notably the Repertory Theatre (CCC 2010b).

The Governor's Bay Road, although suffering from cracks and collapse of some supporting walls, was not closed. This was the only road access into and out of Lyttelton during periods immediately following the event, taking traffic over Dyers Pass or Gebbies Pass.

2.3.5 Effects of the M_w 4.9 Boxing Day Earthquake (26th December 2010)

2.3.5.1 Christchurch Fault

On 26th December 2010, a swarm of earthquakes (the largest at M_w 4.3 at 5km depth) located directly beneath Christchurch CBD caused further distress and limited damage.

2.3.6 Effects of the M_w 6.3 Christchurch Earthquake (22nd February 2011)

2.3.6.1 Port Hills Fault

On 4th February 2011, the Lyttelton Fault sprang to life with a M_w 6.3 shallow event, causing the first fatalities of the Canterbury Earthquake Sequence. A vertical peak-ground acceleration (PGA) of 2.2 g was recorded at Heathcote School, very close to the epicentre, and 1.8 g in the CBD.

The old Lyttelton Road Tunnel toll gate structure was badly damaged during the earthquakes and was removed. The tunnel control building was also extensively damaged and needed to be demolished.

After opening in December 2010 following the Darfield Earthquake, Evan's Pass has been closed since the Christchurch Earthquake. The Christchurch Earthquake again dislodged bolders and loosened bluffs, such that even after much scaling work, the road was not deemed safe to travel and remained closed. The small parapet walls protecting the traveller from the steep slopes down to Gollen's Bay and the harbour were also damaged by falling rocks. The road surface exhibited major cracking perpendicular to the slope.

Dyer's Pass Road was temporarily closed due to rockfall and rockfall danger, but reopened soon thereafter.

Roads throughout Lyttelton and the study area took severe punishment from the Christchurch Earthquake. Many retaining walls, especially those built of red volcanic scoria rock, which were precarious after the Darfield Earthquake failed and diversions and road closures were put in place. Roads through the town were also affected by buildings, either having fallen onto the road or which were threatening to do so. Many roads suffered from unevenness as the base layers were delaminated (due to the high PGA and shaking) and drains and other underground utilities 'floated' in the substrate.

All major unreinforced stone buildings suffered extensive damage. Many other unreinforced masonry buildings suffered from frontages and cladding failure. Many parapets were lost from hotels and other historical buildings. The Lyttelton Timeball building suffered extensive damage. Many chimneys that were still standing after the Darfield Earthquake succumbed to gravity and fell or became unsafe.

Rockfalls caused roads to shut and threatened residents at the outskirts of developments under or close to bluffs. Residents at Hyllton Heights were evacuated due to rockfall danger. A car-sized boulder rolled across Governors Bay Road and crashed straight through a house in Rapaki, leaving a trail of deep indentations across the hillside and paddocks, ending up on a lower roadway. People travelling along Evans Pass Road and over the Bridal Path walkway witnessed boulders the size of cars or busses falling from the surrounding cliffs.

There was little reported liquefaction in Lyttelton.

The Lyttelton port of Christchurch was extremely close to the epicentre. Port wharves, breakwaters, quays and reclaimed land moved significantly – in some instances over a metre laterally and nearly a metre [vertically] (Lyttelton Port of Christchurch 2011).

Figure 2-7 : Damage to wharves at Lyttelton Port (Lyttelton Port of Christchurch 2011)

The water supply to Lyttelton, being fed from Christchurch, was mostly unaffected by the Christchurch Earthquake. There was minor reported damage to water pipes. The waste water system was affected. Residents were affected by a power cut but services were restored to most customers within 24 hours.

A 3.5 m high tsunami wave was created in the Tasman Lake, Mount Cook National Park, as the earthquake triggered icebergs to calve off the Tasman Glacier.

2.3.7 Effects of the M_w 5.8/6.4 Sumner Earthquake (13th June 2011)

2.3.7.1 Sumner Fault

On 22nd June 2011, the Port Hills Fault rattled the study area twice within 2 hours, with large, shallow M_w 5.7 and M_w 6.1 events. One individual died and 46 were injured 2

seriously. A vertical peak-ground acceleration (PGA) of 2.13 g was recorded at the epicentre. The larger event followed the initial, smaller event.

The Lyttelton Tunnel was closed as a precautionary measure but was reopened shortly thereafter. Evans Pass Road remains blocked with further rockfalls and slips reported. Dyers Pass Road remained open but there were reports of small rockfalls.

The roads sustained more damage but retaining walls that were not previously damaged did not sustain further major damage.

Further buildings crumbled and many are in need of demolition. The Lyttelton Timeball building, seriously affected in the Christchurch Earthquake, came down on its own in June. All major unreinforced stone buildings became unrecoverable.

Rockfalls continued from the bluffs.

No major liquefaction was reported.

Further movement and damage to the Port infrastructure occurred (Lyttelton Port of Christchurch 2011).

2.3.7.2 On-going aftershock sequence

The aftershock sequence after the Darfield Earthquake was reinvigorated after each of the subsequent Christchurch and Sumner Earthquakes. This is clearly seen in the chart of number of earthquakes of M_w 3.0 or greater against the timeline (Figure 2-8).

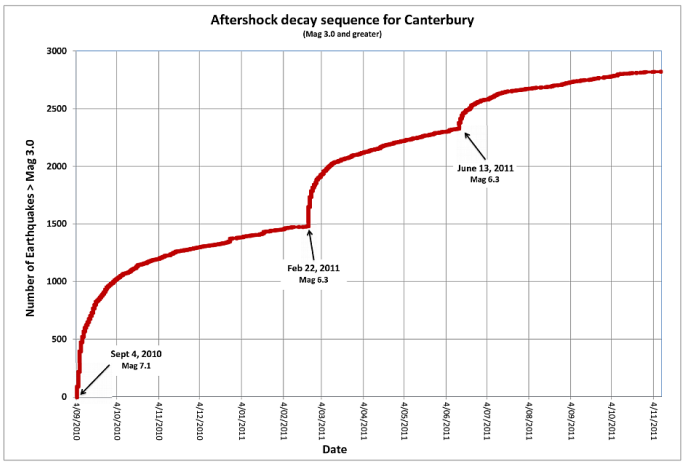


Figure 2-8 : Aftershock decay sequence for Canterbury (Mag 3.0 and greater) (GNS Science 2011a)

It is important to recognise that when dealing with a large earthquake disaster, subsequent aftershocks can be as or more destructive than the initial earthquake, and plans that mitigate further exposure to the hazard should be well-designed and circulated.

2.3.8 Pegasus Bay Seismic Zone

On 23rd December 2011, faults under Pegasus Bay produced four shallow M_w 5.1 to M_w 6.0 events with four hours (Table 0-1-1). Again, the largest of these, with its epicentre under New Brighton coastline, was not the first event.

2.4 Liquefaction and lateral spreading

Liquefaction is a phenomenon whereby soil substantially loses strength in response to earthquake shaking, causing it to behave like a liquid. Liquefaction often causes ground settlement as silt is forced out of the soil. Over larger areas, differential settlement can cause certain parts of a large building or industrial complex to settle more than others. Liquefaction also causes problems with underlying structures, such as tanks and pipes, which can become buoyant and start to float towards the surface.

Liquefaction-induced lateral spreading is defined as the finite, lateral displacement of gently sloping ground as a result or pore pressure build-up or liquefaction in a shallow underlying deposit during an earthquake (Rauch 1997). Lateral spreading occurs when uncontained soils are shaken and start to flow downslope or towards shorelines or river banks. Lateral spread can affect sub-soil infrastructure, such as pipes, as well as buildings and highways, caused by surface spreading and cracking.

After the September 4th Darfield Earthquake, a team from the Department of Geological Sciences, University of Canterbury, was deployed to Lyttelton to map liquefaction at the marina and dangerous goods wharf. This area is built on reclaimed land.

Figure 2-9 : Montage of liquefaction and spreading effects at the Lyttelton Marina and Dangerous Goods Wharf, caused by the Darfield Earthquake

2.5 Tsunami

2.5.1 Near-field tsunami

Lyttelton and the surrounding areas are affected by tsunami physically, economically, and socially, being a coastal town and heavily invested in the harbour. Confined within the natural topography of Lyttelton, a sheltered-harbour environment, it is prone to much-stronger attenuation and amplification of long-period waves than the open coast of Christchurch (Heath 1976).

Near-field tsunami originating in lcoal waters will result in minimal warnings being able to be broadcast. The likely scenarios for near-field tsunami generation are a coseismic event (Walters et al. 2006a) or a submarine landslide (Walters et al. 2006b). The referenced scenarios describe the likely location for these events as surrounding Kaikoura, 100 - 150 km north of the Lyttelton harbour mouth.

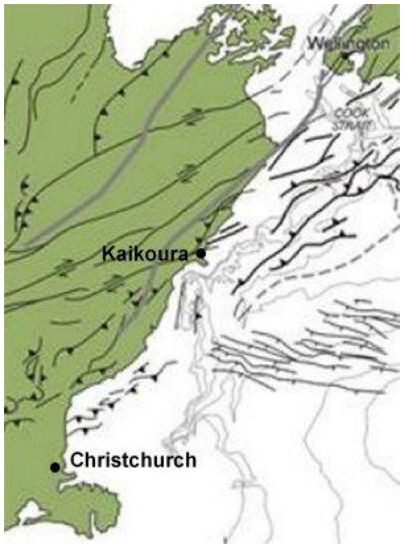


Figure 2-10 : Active sub-sea faults north of Lyttelton (ECan 2010b)

Due to the orientation of the harbour mouth, and the wave-guide properties of the ocean surface, there will likely be not greater that a 2 m tsunami wave affecting Lyttelton harbour. However, the affects of the tsunami will reverberate for a prolonged time, again due to the properties of the ocean floor and the harbour bathymetry (Heath 1976).

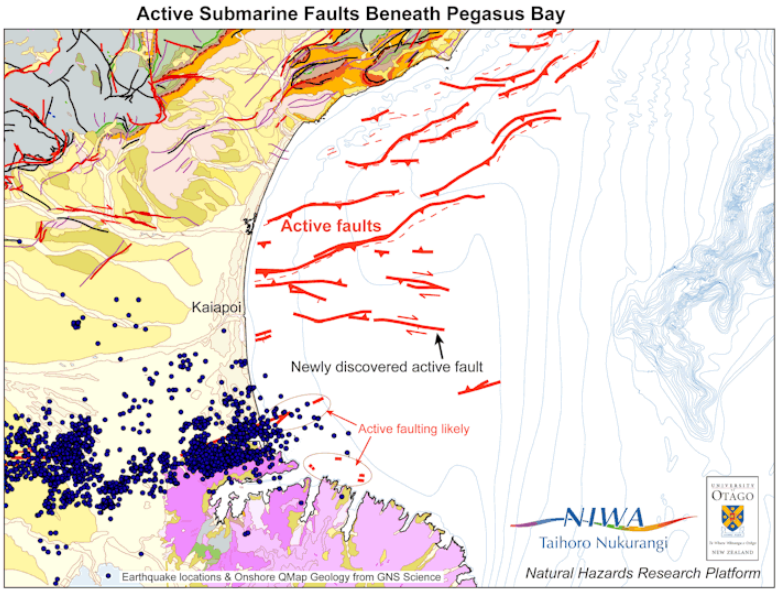


Figure 2-11 : Active submarine faults beneath Pegasus Bay (NIWA, University of Otago) (ECan 2011b)

A survey of the previously unknown faults under Pegasus Bay show that the recently active ones may have a length of 25 km, similar in length to the Greendale Fault, and therefore capable of producing a M_w 6 - 7 earthquake (Barnes 2011). It has been calculated that it would require a M_w 6.5+ earthquake to displace the sea floor enough to create a

tsunami. The small aftershocks experienced in Canterbury over recent months are not big enough to generate tsunami. If a larger earthquake were to occur offshore in the Canterbury region, any resulting tsunami would be small in size and not expected to inundate land (Grant 2012).

2.5.2 Far-field tsunami

Distant tsunamis originating from across the Pacific Ocean will be predictable in their timing but unpredictable in their local strengths, the latter caused by the complex refractive nature of the Chatham Rise, offshore seabed topography surrounding Banks Peninsular, and natural resonance of Pegasus Bay (de Lange & Moon 2009).

Numerical modelling (Downes 2007) shows that tsunami sourced from plate interface effects along the southern coastline of Peru and northernmost area of Chile are orientated in such a way that a large proportion of the wave energy is directed towards New Zealand.

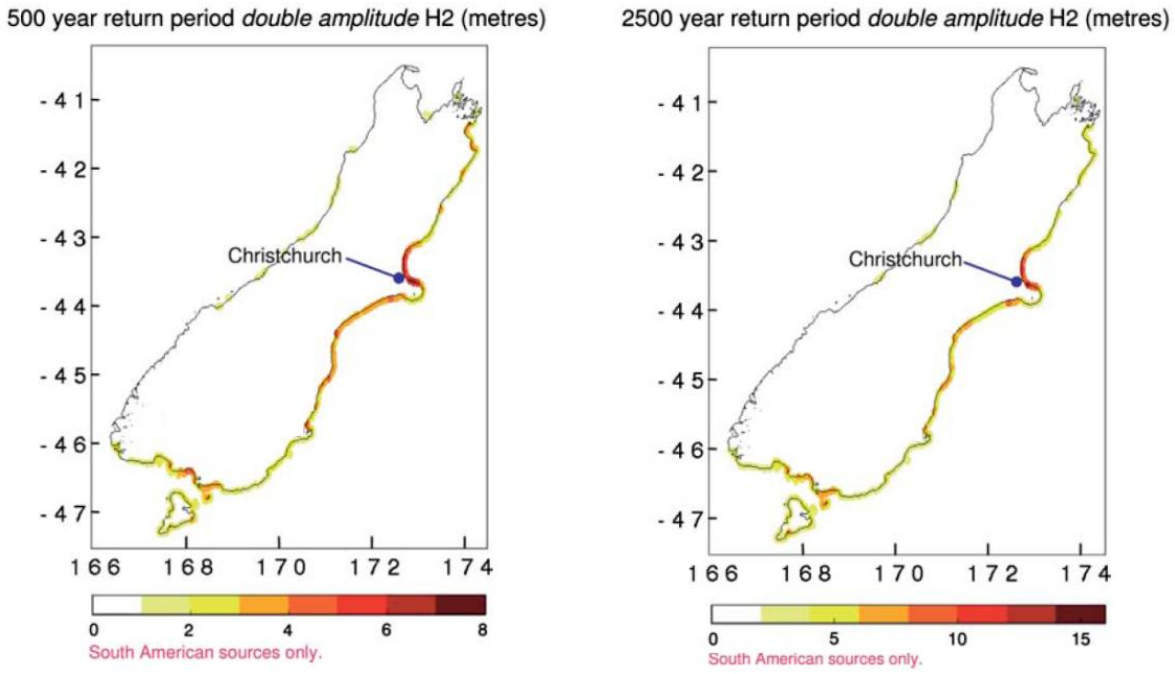


Figure 2-12 : Double amplitude H2 in metres for the 500-year (left) and 2500-year (right) return period South American tsunami for each location around the South Island, New Zealand, coastline (Downes 2007)

(Power & Gale 2010) have created a scenario database that is the result of multiple forecast simulations of possible tsunami-inducing earthquakes at likely locations and strengths. The model has been tested against known historical tsunamis.

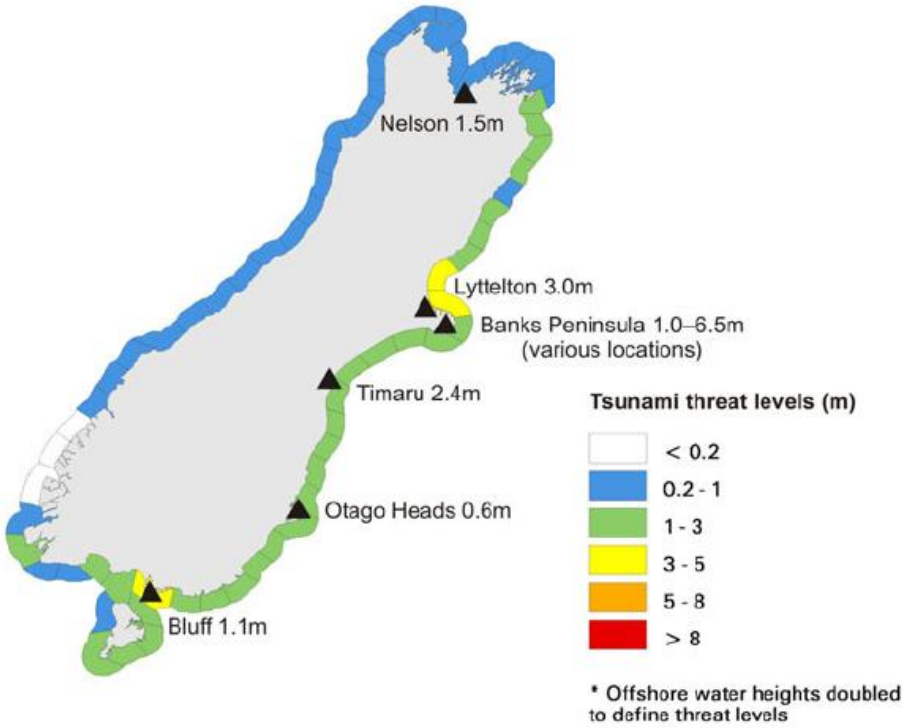


Figure 2-13 : Model results for a Mw 9.0 earthquake in the approximate location of the 1868 Peru earthquake. Superimposed triangles show the estimated maximum water-levels from historical observations of the 1868 tsunami at key locations (Power & Gale 2010)

2.5.2.1 Large, historic events

On 13th August 1868, an earthquake in Arica, Chile, judged to be of around M_w 8.5 in strength, caused the early morning 15th August tsunami that devastated Lyttelton's harbour and ships with a greater than 7m high surge (de Lange & McSaveney 2009).

On 10th May 1877, a great earthquake off the northern coast of Chile, estimated to be of approximately M_w 8.3, produced a smaller tsunami that affected Lyttelton harbour.

The M_w 9.5 Puerto Montt, Valdivia, Chile Earthquake of 1960 produced an observed 2.7m waves with 3 – 4 m run-up height around Banks Peninsula, but due to near low tide, its impact was markedly reduced. Notwithstanding, it damaged boats and electrical gear at the port, and inundated a hotel and several houses: 200 sheep also drowned (The Encyclopedia of New Zealand 2011).

Figure 2-14 : Water poured into the dry dock at Lyttelton, in the South Island, during several of the surges from the Chile tsunami in May 1960.

2.5.2.2 Recent events (Chile February 2010)

On 27th February 2010, a magnitude M_w 8.8 earthquake off the coast of Concepcion, Chile generated a tsunami that caused a 2.2 m surge (Figure 2-15) to enter Lyttelton Harbour (stuff.co.nz 2010b).

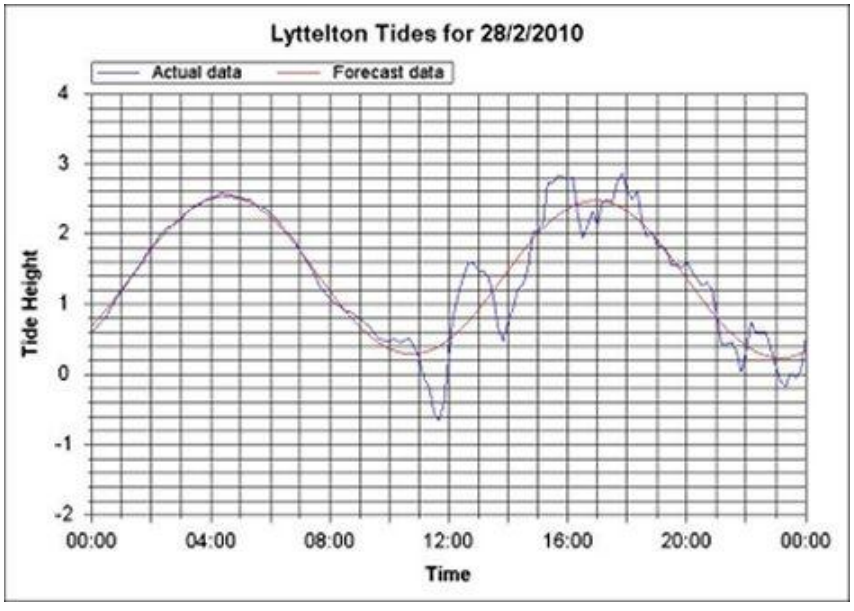


Figure 2-15 : Lyttelton tide gauge 28-Feb-2010

Figure 2-16 : Suddenly strange: (left) Boats sit on the seabed after tsunami surges drained Cass Bay in Lyttelton Harbour (Rudge 2010) – (right) The Governors Bay jetty is covered by tidal surges caused by the Chile quake (Hallett 2010)

The sea at Godley Head was reported to be flowing into the harbour like a river, and exceeding 5 knots headway alongside the wharves (ECan 2010a).

2.6 Slope hazard: Rock fall and landslide

The Port Hills are at significant risk of landslides and rockfalls caused by earthquakes or severe rainstorms. Earthquakes continue to represent a risk of rockfall or slope failure. Slope failure is more common in mid-Winter to early spring when soil moisture levels are high enough to reduce the cohesive strength of loessal soils.

After the recent earthquakes, bluffs and steep rocky slopes are more prone to loosening due to freeze-thaw cycle mechanisms, and cracks and fissures have opened to allow rain water to ingress and cause hard to detect erosion deep within the rocks.

Rainstorm-induced landslides tend to be associated with prolonged wet periods, for example two or more consecutive wet winters, or after a major snowstorm when soil moisture levels are close to saturation. These conditions only require a minimal increase from moderate frequency storms to initiate movement. There appears to be a period of 10-20 years between significant events on the northern slopes of the Port Hills, but rills and fissures develop in the southern-facing slopes surrounding Lyttelton.

In historical times, a landslip behind Hawkhurst Road nos. 54 and 56 caused considerable dismay to the residents, but no structural damage [pers comm - local resident].

Figure 2-17 : Hawkhurst Road historical landslip above nos. 54/56

Figure 2-18 : Large boulders from rock falls on Castle Rock (mainly during the 4 September earthquake) near north Tunnel Portal (P), plus debris on tunnel maintenance road (GNS Photo-GTH_6084).

The Bridal Path was widely used by those on foot to get back to Lyttelton after the earthquakes struck, as the tunnel and Evans Pass Road was closed. Aftershocks caused boulders to fall onto the track and cause at least one fatality.

Evans Pass Road was closed after the Darfield Earthquake but re-opened on 21st October 2010, after scaling work to make safe and remove 15'000 m^3 of loose rock above the road and repair retaining walls alongside the road was completed. After the Christchurch Earthquake, the road was again closed such that further work could be undertaken to make the road safe, but has since not re-opened. During the Christchurch Earthquake, cyclists travelling the route escaped narrowly from falling rocks (Figure 2-19), as did a petrol tank driver (Figure 2-20).

Figure 2-19 : Cyclists dodge rocks the size of busses on Evan's Pass (Photo Andre Chappell)

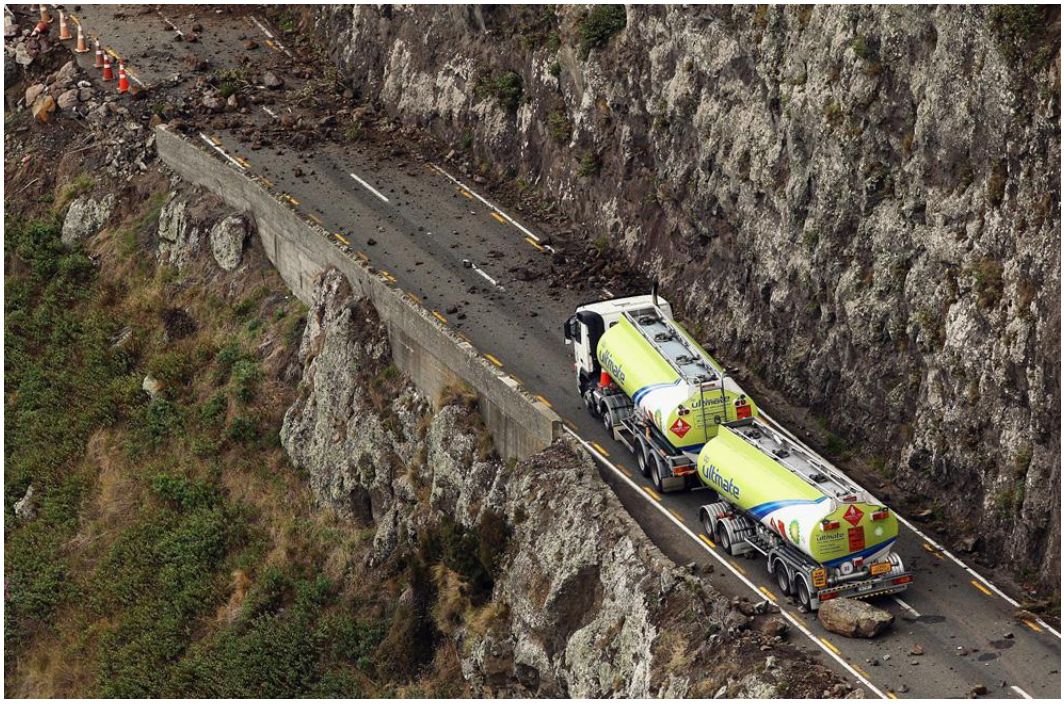


Figure 2-20 : After the Christchurch Earthquake, an abandoned petrol tanker pictured on Evans Pass Road. © The Atlantic 2010

Hyllton Heights, a new subdivision high above Lyttelton, situated below the bluffs of Mt Pleasant, has been zoned red due to the danger of rock fall. The Christchurch Earthquake left a number of houses without roofs, or otherwise severely structurally damaged, and still in danger of tumbling boulders.

Figure 2-21, below, shows landslides and mass ground movements caused by the Christchurch Earthquake, identified during a GNS Science reconnaissance flight (Hancox et al. 2011).

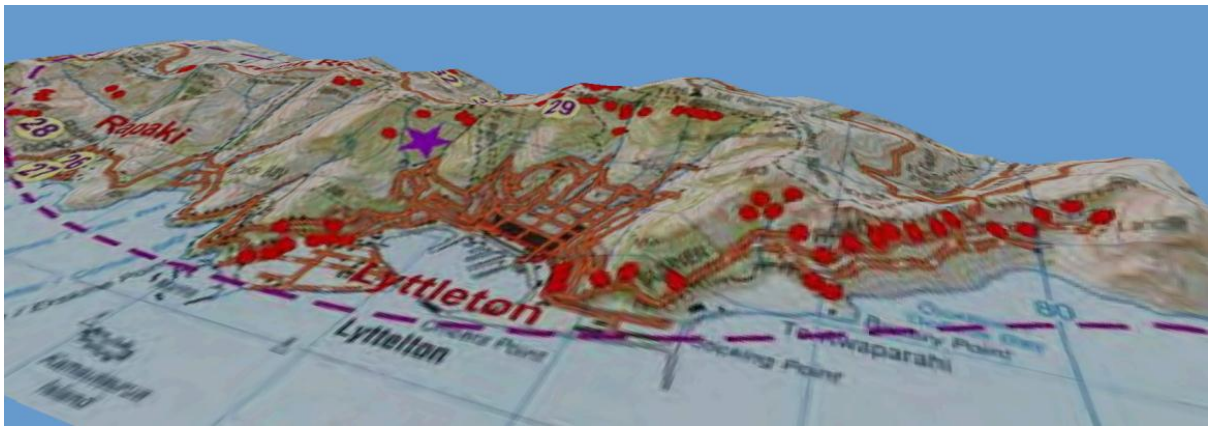


Figure 2-21 : Landslide map, February 2011, with Christchurch Earthquake epicentre marked - from (Hancox et al. 2011)

Figure 2-22, below, shows areas where boulders threaten infrastructure and landslides and mass movements have occurred in Lyttelton and surrounds.

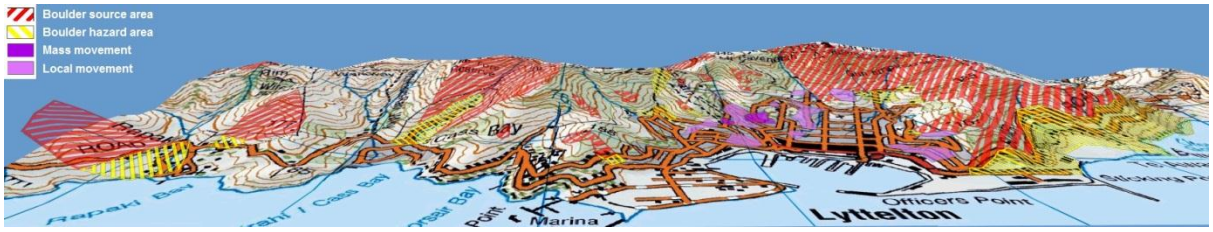


Figure 2-22 : Local failures - mass movement and rockfall – after (McFarlane 2011) - draped over 90m DEM

Many of the retaining walls in Lyttelton are constructed from the local, red scoria rock. They were not resilient during the Darfield Earthquake and failed catastrophically after the Christchurch and Sumner Earthquakes.

Figure 2-23 : Failure of retaining wall: St David's Street (above), Sumner Road (below), looking along Sumner Road towards Evans Pass.

The extremely high ground-shaking during the Christchurch and Sumner Earthquakes in the northern Port Hills lead to extensive rockfalls and rock slope failures. Rockfalls mostly occurred from the jointed lava flows, leading to tens of houses being impacted by falling rock in Lyttelton and Rapaki (Giovinazzi et al. 2011). The time of day (mid-day) meant few were occupied which reduced the number of potential casualties. In Rapaki, a boulder dislodged from the hills above, bounced over Governors Bay Road, rolled through a house, tumbled through a paddock, and came to rest in the road below.

Joint-controlled lava blocks were dislodged from lava flow outcrops often high up on the slopes of the valleys and bluffs in the Port Hills. Once dislodged, these blocks could in some

cases roll, bounce and slide hundreds of metres before coming to rest, either as the slopes flattened out, or at the bottom of valleys (Dellow et al. 2011).

Figure 2-24 : Source area (S on 405 m peak) and travel path of the boulder (B) that hit the house 241 Governors Bay Road (H) at Rapaki *(GNS Photo-GTH_5853)*. Inset right - House at 241 Governors Bay Road, Rapaki, 3 km west of Lyttelton, showing the entrance path of the large (~3 m long) boulder *(GNS Photo-GTH_5842).*

Figure 2-25 : Where the rock came to rest (Photo: Julian Idle)

The mitigation measures in place (fences, benches and trees) were overwhelmed by the large number and volume of rocks, which came down off the hills (Bell 2011).

2.7 Loess-colluvial tunnel-gulley erosion

The then-Lyttelton Borough Council cut two rough vehicle tracks across the Lyttelton Reserve in the mid 1970's to provide access for a shrub planting programme (Yetton 1986). It was also hoped that the tracks would help direct slope water away from Council-owned

rental properties along Foster Terrace. Tenants in these properties had complained of water flowing off the reserve and saturating their sections.

Over the following 5 years, erosion tunnels developed under the tracks where, in many cases, existing tunnels had simply been filled over. Although the track had a slight crossfall into the slope, a side channel had not been fully formed and was never lined. During rainstorms water had opened sinkholes to the tunnels passing underneath, and in this manner the tunnels effectively enlarged their catchments.

By November 1983, one property, at 14 Foster Terrace, was particularly badly affected by water off the reserve.

In a study for Christchurch City Council (Trangmar 2003), the areas suffering from tunnel-gully erosion was given as (Table 2-8):

Table 2-8 : Areas affected by tunnel-gully erosion

Total area of study area in Lyttelton:	2587.4 ha	
Of that affected by tunnel-gully erosion:		
Slight:	264.8 ha	(10%)
Moderate:	68.8 ha	(3%)
Severe:	196.0 ha	(8%)
Indeterminate:	0.8 ha	(<1%)

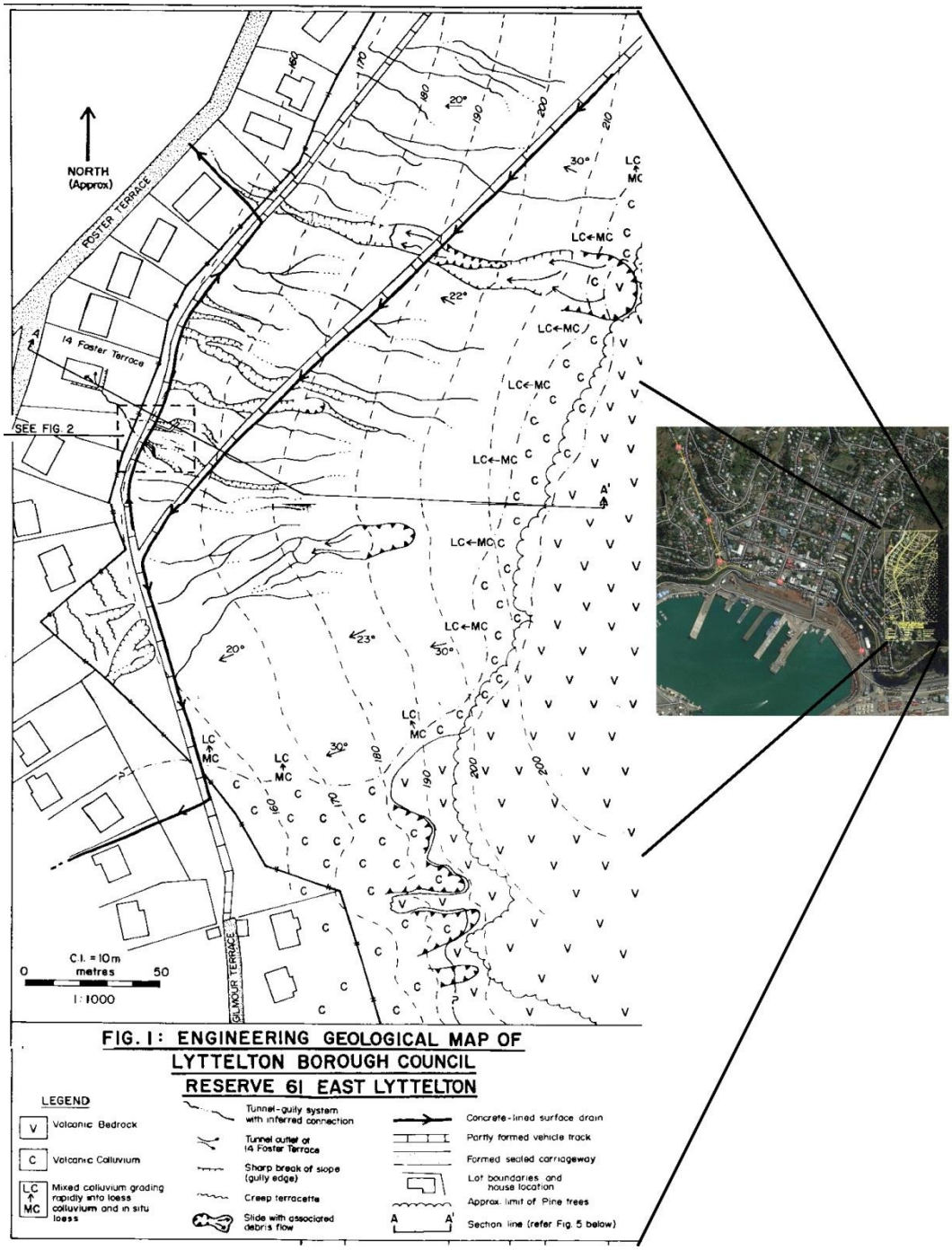


Figure 2-26 : Engineering geological map of Reserve 61, East Lyttelton, after (Yetton 1986)

The slope above the house in Rapaki that was hit by the boulder (No. 241 Governors Bay Road), above, is filled with rills and tunnel-gully erosion through the loess-colluvial soils (Figure 2-27).

Figure 2-27 : Rills and tunnel-gully erosion through loess-colluvial soils above Rapaki

2.8 Storm

Lyttelton does not experience the intensity of rainfall that occurs in other parts of New Zealand. Generally, 24-hour rainfall with return periods of five years produces 100 – 150 mm on the Port Hills. The effect of heavy rainfall is covered in the flood hazard and slope hazard sections.

The most severe winds are associated with north-westerly and southerly airflow over the South Island. Severe events occurred in 1945, 1964, 1975, and 1988. The peak wind in Christchurch in 1975 was 193 km/h, which exceeded the 100-year return period (CCC 2003). Extreme winds can cause personal injury and death, and extensive damage to buildings, vegetation, and infrastructure.

It is possible that during a strong Nor'Wester a vortex could touch down on the leeward hillsides. Winds may gust up to 40 knots in the harbour: the warmer the air the stronger the gusts! The Nor'west winds seem to funnel near the Corsair Bay area.

Gale force winds occur roughly twice a year. In October 2000, the storm is estimated to have caused $8m worth of damage to the incomplete Lyttelton marina, sinking many yachts in the process (Salinger et al. 2000)

In November 2009, high winds blew a container ship off its moorings. In June 2010, "humungous" waves sank two boats in Lyttelton harbour, with wind gusts reaching 111 km/h causing two-metre-high waves (Williams 2010).

A significant tornado event was recorded in Governors Bay in 1975 (CCC 2003).

Lightning has been recorded at Lyttelton, on the Port Hills. Electrical storms tend to occur between September and March but are relatively infrequent. With lightning comes the possibility of house or vegetation fire, or even death for walkers in the hills.

Canterbury normally has one significant hail storm a year, usually between October and March (CCC 2003). No damaging hail storm has been recorded for Lyttelton.

2.9 Flooding

Lyttelton is built high up from the mean high-tide mark, so only tsunami and extreme storm surges would endanger the population. Stream breakout, especially coupled with storm and snow melt, could cause floods to occur in parts of the study area, perhaps even causing road and bridge washouts. Areas such as Cass Bay, where streams are channelled through residential areas, pose serious issues of flooding if the channels are not kept clear and upstream debris within the catchment not removed.

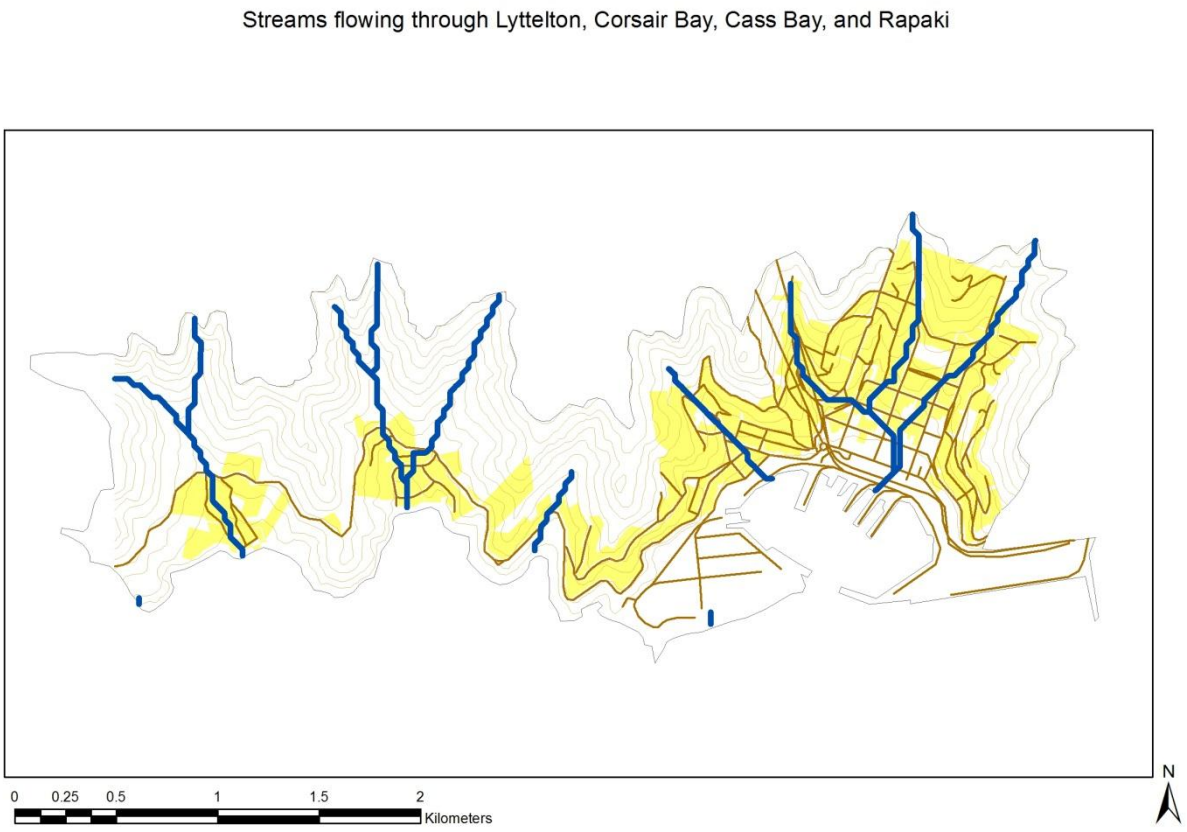


Figure 2-28 : Streams flowing through Lyttelton, Corsair Bay, Cass Bay, and Rapaki

2.10 Snowstorm

Significant snowstorms have occurred in 1895, 1896, 1901, 1918, 1945, and 1992. Snow storms cause damage to buildings and power lines, disruption to traffic and communications, and stock losses in rural districts (CCC 2003). A secondary effect is snowmelt flooding, which could induce mass-movement of slopes due to soils reaching saturation.

Due to its steep slopes, walking or driving in Lyttelton is perilous. The snow storm that enveloped the greater Canterbury region in July 2011 caused chaos in Lyttelton due to inaccessibility and steep, icy roads. In the days following the snow, the roads were still difficult to navigate due to the attempts of authorities (CCC 2011a) and locals in spreading gravel on to the icy surfaces that resulted later in driving and walking on what appeared to be ball-bearings (pers comm – the author).

2.11 Fire

The historic fire of 24th October, 1870 destroyed the commercial centre of Lyttelton. Not having a fire brigade at the time, residents were forced to destroy buildings to create a fire break in order to save the rest of the town. It was New Zealand's most extensive urban fire to date.

Fortunately, the Darfield Earthquake of September 2010, although it caused chimneys to collapse, did not occur when those chimneys were in use, thus reducing the risk of fire in the aftermath of the earthquake.

Some of the 148 fires reported in the 4 days after the Hyogoken-Nanbu (Kobe) Earthquake of 1995 were caused directly by the earthquake as people were cooking their breakfasts, but 25% were attributed to the restoration of power igniting damaged reticulated gas supplies (Borcherdt et al. 1998). The fires were also hard to extinguish due to the typical wooden houses, narrow streets blocked by debris, and the lack of water.

Unlike in some parts of the country (such as Wellington), gas is not reticulated to homes in Lyttelton, so there were no gas mains to break during the earthquake events.

The risk of fire was also significantly reduced in the wintertime earthquakes in June as weak chimneys had already been felled in the Christchurch Earthquake and were therefore not in use.

2.12 Drought

On average, the Canterbury region is affected by one significant drought about every six years. Since 1970, severe droughts have occurred in 1977-78, 1985, 1988-89, 1992, 1997-98, 2000-01, and 2002-03 (CCC 2003). Lyttelton is not a directly agricultural-based economy and so did not suffer losses. However, drought does increase the risk of fire and allows the fine loessal soils to dry out and winds cause dust to be blown into the air, increasing respiratory conditions.

2.13 Heatwave

Lyttelton has not been affected by a heatwave since records began. This is probably due to its disposition close to the harbour and the predominantly South-facing aspect.

2.14 Pandemic

Pandemics are worldwide outbreaks of disease or viruses. Being an international port catering for cruise liners, Lyttelton is on the front line. SARS and H1N1 (bird flu) were heavily reported in the media, but once the number of infections had died down and other news interested the media, coverage has waned. This is not to say either threat has gone away, as recent reports and warnings by the United Nations testify (World Health Organisation 2011).

2.15 Explosion

Stringent safety procedures have been put in place by the Lyttelton Port Company when unloading hazardous goods, such as LPG and fuel. Downstream operations by the tank farm owners also need to be of the highest quality. Even in the heavily-regulated oil & gas industry in the United Kingdom, accidents such as Buncefield, UK, have occurred (Buncefield Major Incident Investigation Board 2007), so their findings regarding societal risk can inform local operators (Buncefield Major Incident Investigation Board 2008).

2.16 Noxious vapours

Release of noxious chemicals (in aerosol or gaseous form) into the atmosphere and their dispersion is subject to the wind conditions and topography of the area, as well as their specific gravity (which helps define their propensity to sink or rise through the surrounding air column). Noxious vapours can cause nausea, headaches, fatigue, and other symptoms, especially if those affected have long-term exposure (Akland 1993).

The Lyttelton hazardous goods wharf and surrounding tank farm is overlooked by residential properties. LPG (a mixture of butane (C_4H_{10} – 2.0061) and propane (C_3H_8 – 1.5219)) (Engineering Toolbox 2011), petrol (C_8H_{18} – 0.71 to 0.77), and diesel ($C_{12}H_{23}$ – 0.82 to 0.95) (SImetric 2011) are stored in these tanks. LPG vapour is heavier than air, and therefore has a propensity to sink to the ground, whereas petrol and diesel vapour have a specific gravity less than air, causing them to rise. Notwithstanding the possibility of an inversion layer forming within the Lyttelton Harbour, the tank farm at Lyttelton is surrounded by a 20m cliff to the north which, together with a southerly wind, can cause vapours to be trapped or be swept towards the main town.

The Lyttelton wastewater treatment plant was constructed in 1996 and is located below Sumner Road between the container terminal and the coal stockpile yards of the Lyttelton Port Company. Methane (CH_4 – 0.5537) is usually generated in the anaerobic digestion process used to break down sewage by bacteria. This unpleasantly pungent gas can be detectable in surrounding houses near to the Timeball during an easterly.

2.17 Terrorism

Being a strategic regional asset, Lyttelton Port is a prospective terrorist target. Although New Zealand is not seen as a high-risk target for terrorist activity, it can be used as a transit country for an attack on Australia. Depending on the nature of the attack, an unforeseen incident could therefore occur at Lyttelton.

3 Research Methodology and Data Collection Techniques

3.1 Context

The research project commenced shortly after the 26th February 2010 (M_w 8.8, MM IX) Chilean Earthquake (National Oceanic and Atmospheric Administration (NOAA) 2012) which generated a tsunami that affected Lyttelton Harbour (Lyttelton Port of Christchurch 2010). The original research used that tsunami event as a base-line for a natural hazard event to inform the sampled community. Two written surveys were conducted during this study: the first, prior to the 4th September Darfield Earthquake; the second, after the 13th June Sumner Earthquakes.

Concurrent with the 2010 survey, a structured interview comprising of 6 questions was carried out at random households. The interview was suspended after the 4th September Darfield Earthquake. A passive census of parked vehicles was also carried out in mid-2010 on different days of the week and at different times, acting as a proxy to population movement and distribution.

The 22nd February 2011 M_w 6.3 Christchurch Earthquake changed the research focus entirely, and a new survey of the original 500 recipients of the pre-September survey was commissioned for delivery after the government moratorium on social sciences research was lifted on 31st May 2011. Before this survey was ready, the 13th June M_w 5.7/M_w 6.0 Sumner Earthquakes happened. The survey was quickly broadened to accommodate the Sumner Earthquakes, and expended to a complete census of the 1'400 households in Lyttelton, Corsair Bay, Cass Bay, and Rapaki. This census was carried out in the period July – August 2011.

3.2 2010 Written Survey

The 2010 written survey was implemented prior to the M_w 7.1 September 2010 Darfield Earthquake. It was conceived as a written preparedness survey due to the breadth of the information being requested. The survey was anonymous and confidential.

To inform the objectives of the research concerned with preparedness, the survey incorporated questions regarding triggers to evacuation, meeting places and emergency plans, provisions, community relationships, and household demographics.

To inform the objectives of the research concerned with vulnerability, the details of locations and activities of household members throughout the week in three-hourly intervals were also requested in order to build a spatiotemporal population distribution model. Furthermore, vulnerability to loss of utilities or house structure was inferred by asking about the type of structure and foundation the house was built on, age and general state of repair of the house, and necessarily layman's geotechnical observations from the respondents.

To inform the objectives of the research concerned with the immediate response to recent disasters, there was a specific reference to the tsunami at the end of February 2010, which was regarded as a baseline experience of a natural disaster to inform the respondents' answers regarding their experience of other disasters and their anticipation for another.

A sample size of 500 was chosen due to cost constraints. Each package contained a cover letter, the survey (a 12-page booklet format, monochrome printed on 3 double-sided A4 leaves, folded to A5, and centre stapled), and a C5 reply-paid addressed envelope, all stuffed into a C5 envelope with University of Canterbury logo and researcher contact details, and addressed to ***The Occupant***. Each survey was uniquely numbered using a self-inking self-incrementing number stamp and the same number stamped on the envelope. The written surveys were randomly and evenly delivered by hand to post boxes within the study area (every second or third mail box). As each survey was posted it was geo-tagged using a Trimble Juno SB handheld with integrated GPS running Trimble TerraSync data collection software.

The result geo-tagged data files were processed using Trimble GPS Pathfinder Office software and exported to various formats, including KML (Keyhole Markup Language) for viewing preliminary survey distribution data in Google Earth, text file in tabular format for later collation with returned survey data, and Esri ShapeFile for use in Esri ArcGIS to perform spatial analysis with the data.

To provide anonymity, the survey number and the geo-tag is only known to the principal researcher and kept separate from the raw data.

To complete the 500 samples, remaining written surveys were delivered a few days after the Darfield Earthquake.

The date of delivery of each survey to the mailbox was recorded, as well as the time it was posted (date printed on the cancellation mark on the return envelope). Because surveys were being delivered in the evening immediately before the Darfield Earthquake, some were not received until after the earthquake. This means there are three groupings:

Table 3-1 : Temporal distribution of the 2010 written survey delivery and replies

Delivery and receipt dates	Count	Column % N=81
• **Surveys received and returned before the Darfield Earthquake**	18	22%
• **Surveys received before the Darfield Earthquake and returned after the Darfield Earthquake**	31	38%
• **Surveys received and returned after the Darfield Earthquake.**	32	40%

A brief analysis of the results was performed and no significant bias was indicated for return rates: 63% (317) of surveys were delivered before the Darfield Earthquake and 37% (183) afterwards. Of those returned, 60% (49) were delivered before the Darfield Earthquake and 40% (32) afterwards.

The answers of the surveys returned after the Darfield Earthquake were affected by the recipient having experienced the earthquake, most notably recognised in the record of previous earthquakes felt. Some respondents made mention that they filled out the survey as though they had not experienced the earthquake, others mentioned the effects of the earthquake on their property: chimneys down, etc.

The replies were hand-coded into a Microsoft Excel spreadsheet. The spreadsheet was then combined as a data table with the survey delivery spatial data in Esri ArcGIS to produce spatial maps.

3.3 2010 Structured Interviews

A further 6-question face-to-face doorstep interview was conducted at the same time as the 2010 survey delivery. The interviews concerned the likelihood to evacuate, travel plans, and meeting plans, and therefore informed the research objective concerning preparedness of the population for a disaster.

(McFarlane & Garland 1994) indicate that the respondents in their trial were more likely to respond to the face-to-face interview. Furthermore, the presence of the interviewer did not necessarily yield greater amounts of information, nor did their results show any conclusive difference in the quality of responses. For this study, sufficient resources were not available to attempt to survey everyone in the sample population to the depth of the written survey. To save further time, only a third of the sample population was selected to take part in the face-to-face interview.

Every 10th house where a survey was to be delivered was also approached. If no answer came from inside when the door knocked or bell rung, the written survey was delivered and the face-to-face doorstep interview was attempted at the 10th house further along. If the person that answered the door was obviously under age, they were requested to fetch an adult: if one was not available, the interview was terminated and the written survey delivered in the mailbox when leaving. If the person that answered the door was an adult, the purpose of the survey was explained and they were invited to answer the 6 questions. The replies were coded immediately into the Trimble Juno SB handheld and also geo-tagged. At the end of the interview, the respondent was invited to participate in the written survey, and if they accepted, they were handed a survey and the number recorded.

Due to the 4th September Darfield Earthquake, the interviews were suspended after 26 deliveries. The last interviews were carried out on the evening of 3rd September, the last one being just eight hours before the 4th September Darfield Earthquake.

3.4 2010 Parked vehicle census

The parked vehicle census was conducted to collect information regarding where vehicles were located at different days of the week and times of day. This information was used as a

proxy to population movement and distribution to help inform the research objective concerning population vulnerability.

The census was carried out on Sunday late afternoons, Monday early afternoons (before end of school), and Wednesday evenings. It was carried out from the public Right Of Way (ROW); therefore, vehicles not visible from the footpath (for instance, in closed garages or on private property not visible from the public ROW) were unable to be sampled.

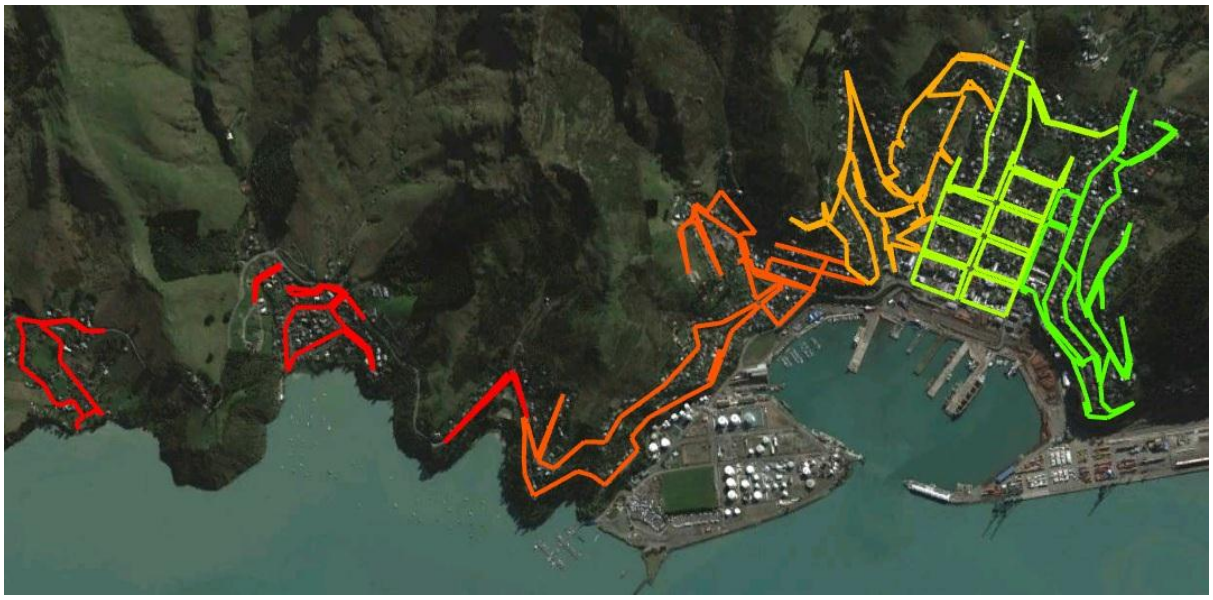


Figure 3-1 : Walking route used to survey vehicles (5 sectors)

Because of the distance involved and the limited time available for each day's time slot, the study area was split into 5 sectors and each sector walked three times, each on the designated day and the designated time, but in different weeks. The total length of a single route is ca. 37 km.

Each vehicle was identified by the license registration plate (if visible), and certain characteristics were recorded. All information was recorded on a Trimble Juno SB handheld with integrated GPS running Trimble TerraSync data collection software. The data sets were uploaded to Trimble GPS Pathfinder office, where they were post-processed (to increased spatial accuracy) and exported to various formats, including KML for viewing preliminary vehicle distribution data in Google Earth, text file in tabular format for later collation with returned survey data, and Esri ShapeFile for use in Esri ArcGIS to perform spatial analysis with the data.

3.5 2011 Written Survey

The 2011 survey was originally conceived to be delivered after the 22nd February Christchurch Earthquake moratorium on research was lifted on 1st May 2011 (Johnston 2011), but was reworked after the 13th June Sumner Earthquakes to incorporate responses to those earthquakes.

Ethical considerations were addressed by sending the survey for review by social science and psychology researchers: Dr William (Deak) Helton (Department of Psychology, University of Canterbury), Kim Wright (GNS Science), and Dr Sarah Beaven (Department of Geological Sciences, University of Canterbury) all reviewed the survey and offered comments. As with all research conducted by the University of Canterbury, approval was sought and received from the University of Canterbury Human Ethics Committee.

A complete census of 1'400 households in the study area was chosen, mainly enabled by financial support from the Canterbury Civil Defence and Emergency management group.

The census asked many of the same questions as the 2010 survey, but also asked specific questions about where people were and their actions after each of the Christchurch and Sumner Earthquakes. This additional information allowed comparisons between the Christchurch and Sumner Earthquakes to be made, and to inform the research objective concerning the preparedness and the immediate responses of the population to the events.

A census format was chosen so all households would be sampled. Each package contained a cover letter with important contact information fact sheet for earthquake victims on the reverse, the survey (an 8-page booklet format, full-colour printing bled to edge on 2 double-sided A3 leaves, folded to A4, and centre stapled), and a C4 reply-paid addressed envelope, all stuffed into a C4 envelope with University of Canterbury and CDEM logos and researcher contact details, the name of the survey and "**Census**". Each survey was uniquely numbered by hand and the same number written on the envelope. This number was known as the "*Internet Serial Number*". The census was also available to participants to take online using a Qualtrics survey tool (Qualtrics 2011). Of the 521 replies received, 31 (5.9%) were completed online.

A postcard was also designed to appear attractive, with a colour University of Canterbury logo on the front and information pertaining to the survey on the rear, including a hyperlink to an online copy of the cover letter and explanatory text for the survey (http://www.nhrc.canterbury.ac.nz/julian_idle.shtml). Each postcard was also uniquely numbered by hand.

The hand-written numbers on the survey and the postcard were also appended with a two-digit checksum to avoid fraudulent replies: no fraudulent replies were received, however. Online surveys were only allowed to use the ISN once in order to avoid duplicate submissions.

The surveys and postcards were hand-delivered at least once to each accessible household, with a second delivery of either, i. a second census package or, ii. a reminder/thank you postcard two weeks later. As each survey or postcard was delivered it was geo-tagged using a Trimble Juno SB handheld with integrated GPS running Trimble TerraSync data collection software, and the street number recorded. If a house was unoccupied, demolished, or there was a vacant plot, this was recorded in the collected data.

Because of the accuracy of the geo-tagging, it was possible to know all of the Internet Serial Numbers that were delivered to a single mailbox, thus making duplicate returns (whether physical or online) detectable. As a precaution, the street number was also recorded alongside the GPS coordinates. Two sets of duplicates replies were received during the course of the survey: two written surveys from the same address; and, one written and one online survey.

The census was further socialised in the media in the Mainland Press (Doudney 2011).

Inaccessible, missing (demolished), or vacated houses were noted and the addresses used to attempt later delivery of the full package using New Zealand Post-paid postal delivery. This method was used to involve recipients that had moved out of the study area.

The result geo-tagged data files were processed using Trimble GPS Pathfinder Office software and exported to various formats, including KML for viewing preliminary survey distribution data in Google Earth, text file in tabular format for later collation with returned

survey data, and Esri ShapeFile for use in Esri ArcGIS to perform spatial analysis with the data.

The written replies were hand-coded using a special version of the public-facing Qualtrics survey that did not have the special navigation or verification logic. The results of the two Qualtrics surveys were downloaded from the Qualtrics survey manager and combined into a Microsoft Excel spreadsheet. The spreadsheet was then combined as a data table with the survey delivery spatial data in Esri ArcGIS to produce spatial maps.

3.5.1 2011 Survey design

Because of the relatively low 16.2% reply rate from the 2010 survey, there was a wish to increase this value. The single point of contact with the 2010 survey was determined to be one reason for the low return rate. A further factor was the quality and size of the survey. Thirdly, it was predominantly a student research project and possibly not taken as seriously as hoped. It has been suggested that high response rates are achieved through five design elements of the survey (Dillman 1999):

- Respondent-friendly questionnaire
- Four contact by mail, plus a special contact
- Return envelopes with real stamps
- Personalisation of correspondence
- Token prepaid financial incentives

3.5.1.1 Respondent-friendly questionnaire

The envelope was made to be more official and less like junk mail. It had the University of Canterbury and CDEM logos, with the name of the census, the information that it was being delivered to all residents in the study area, and the word "**Census**" in the middle.

Inside, a full-colour cover letter with fact sheet of useful contacts was provided for reference. The design of the questionnaire was also made more official looking. It was modelled on the NZ Statistics 2011 census that was cancelled due to the earthquakes. The printing was in full-colour with bleeding to the edge of the paper. The pages were large and accessible and the questions well-spaced. The A4 size when folded had the effect of it not being so easily lost or mislaid.

The postcard was of the attractive University of Canterbury logo in full-colour. On the reverse was a small amount of information and the suggestion to visit the researcher's web page at the university web site.

3.5.1.2 Four contact by mail, plus a special contact

Due to cost constraints, the survey was delivered by hand. Also, a database of addresses was not available to the researcher at the time the survey was delivered.

According to (Dillman 1999), the most success from a mail survey is when the researcher has five contacts with the recipient:

- A brief pre-notice letter
- A questionnaire
- A thank you postcard
- A replacement questionnaire
- A final contact

Due to timing constraints, a pre-notice letter was not delivered. The article in the Mainland Press did fulfil some of the criteria, albeit after the first surveys had been delivered. The survey was delivered at least once, with either a follow-up survey package (the replacement) or a postcard. No final contact was attempted.

3.5.1.3 Return envelopes with real stamps

Due to cost, it was not possible to invest in the number of stamps required to attach to all replied-paid envelopes in the delivered surveys. For this reason, the pre-paid University authorised envelopes were used. Only those replies returned would be charged.

3.5.1.4 Personalisation of correspondence

There was nothing in the correspondence that was sent, other than the ISN was hand-written.

3.5.1.5 Token prepaid financial incentives

This was not considered for ethical reasons.

3.6 Response rate

From the sample of 500 surveys delivered in the 2010 survey, N=82 (16.4%) surveys were returned.

Of the 1’400 surveys delivered in the 2011 survey, N=520 (37.1%) were returned. This included 36 replies online using the Qualtrics Internet survey.

4 Exposure and vulnerability of the population of Lyttelton and surrounding area to hazardous events

3'075 people regularly live in the study area, in 1'326 occupied dwellings (Statistics New Zealand 2006c). 1'400 households were identified during the course of this study. Of the 500 households sampled prior to the Darfield Earthquake, N=82 (16%) replied. Of the 1'400 households sampled in July-August 2011, N=520 (37%) replied.

This chapter uses the aggregate data gathered from the 2010 and 2011 surveys. It is recognised that due to the smaller sample size, the 2010 survey data has a statistically lower confidence level than that from the 2011 survey. The treatment of the data sets from these two surveys should therefore be treated as two separate populations.

Because the questionnaires were geo-tagged at the time of delivery, it was possible to identify 55 replies in common from the 2010 and 2011 as having been delivered to the same addresses. Of those, 50 households were identified as being common between the 2010 and the 2011 June surveys. The remaining 5 households were not deemed to be the same due to a significant change to the household's demographics between 2010 and 2011.

Statistics taken from Statistics New Zealand are obfuscated to conserve confidentiality. This results in percentages that do not sum to 100%.

4.1 Population variables

4.1.1 Age and Gender (2011 survey)

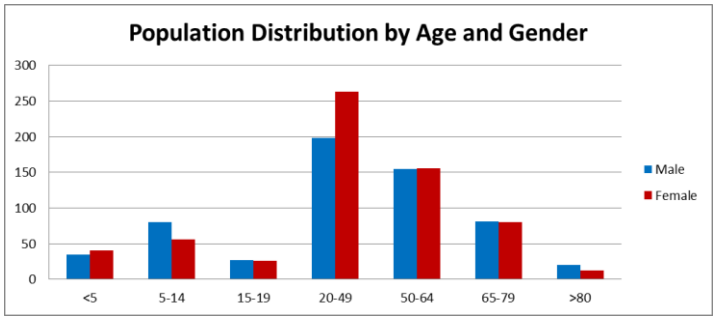
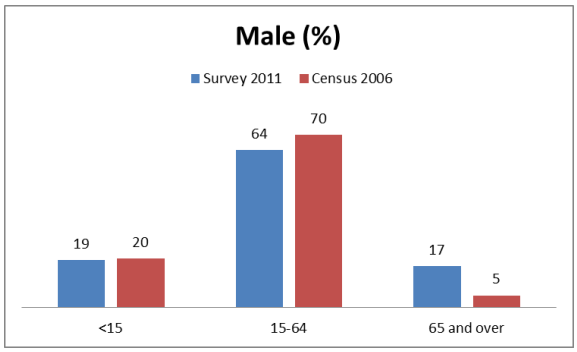


Figure 4-1 : Population distribution by Age and Gender

70% of respondents' households participating in the 2011 survey were made up of adult couples, 20-years and older. 11% of couples were retired (65-years or older). The 2011

survey captured proportionally more replies from retirees than would be expected when compared to the 2006 census data age distribution.



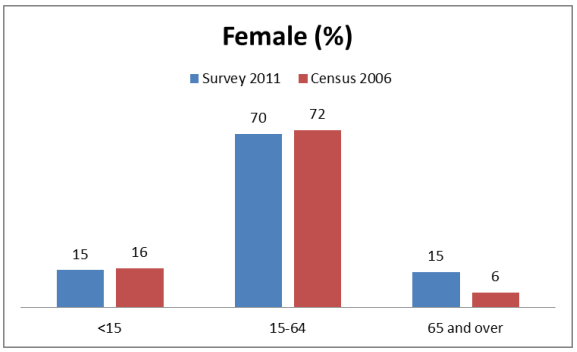
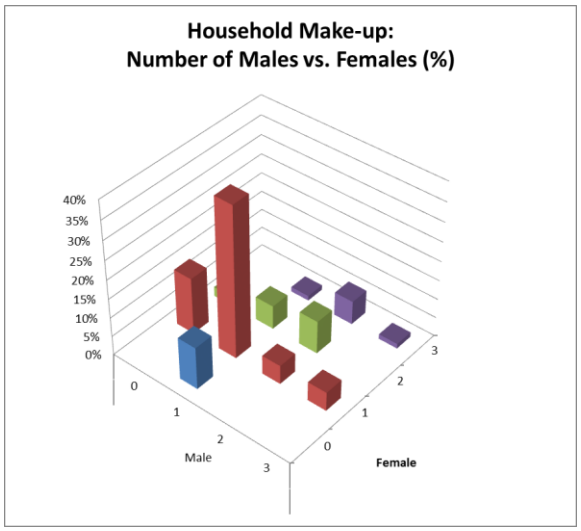


Figure 4-2 : Disproportionally more retirees answered the 2011 survey than accounted for by (Statistics New Zealand 2006c). Males are also slightly underrepresented in the 2011 survey returns.

The 2010 and 2011 surveys allowed the opportunity to analyse the mix of males and females in each household. They both revealed that households were predominantly made of one male and one female. However, the 2010 survey showed there were more single females in households that replied than in 2011.



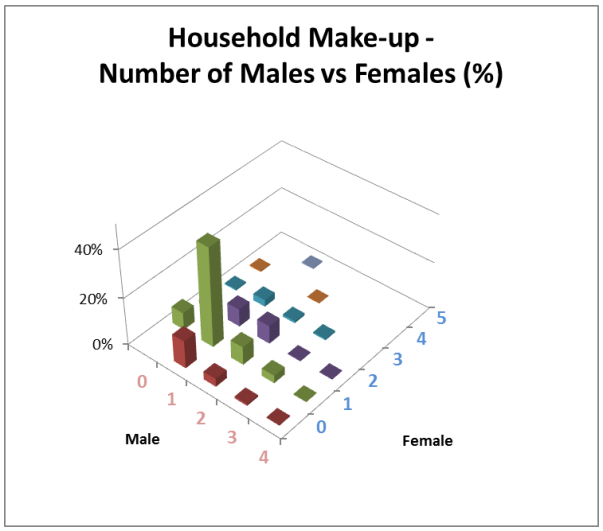


Figure 4-3 : Household make-up - number of Males vs. Females (%) – 2010 Survey

Figure 4-4 : Household make-up - number of Males vs. Females (%) – 2011 Survey

4.1.2 Children

Of the 520 households participating in 2011 Survey, 25% indicated they had children. This compares with 47% in (Statistics New Zealand 2006c). Of those with children, couples with

children made up 19% of the sample, and single parents a further 3%: this compares with 38% and 15%, respectively, in (Statistics New Zealand 2006c).

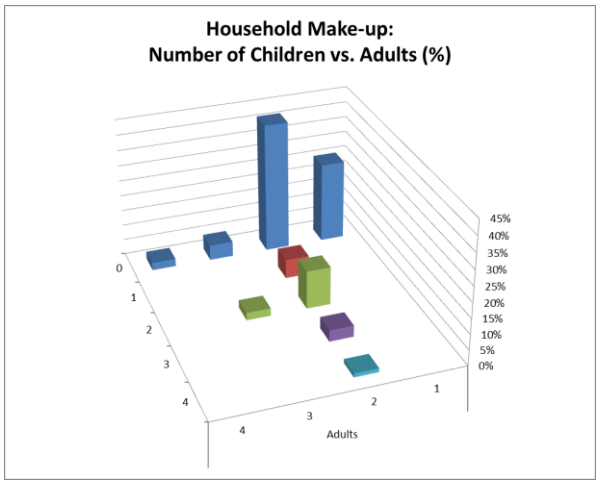


Figure 4-5 : Household make-up - Children vs. Adults (%) – all households - 2010 Survey

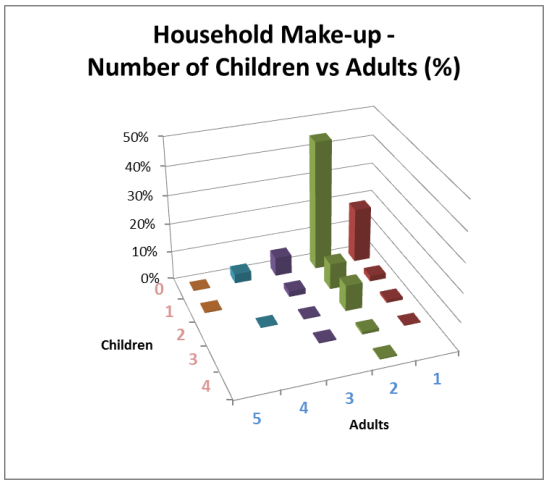


Figure 4-6 : Household make-up - Children vs. Adults (%) – all households - 2011 Survey

No single parents participated in the 2010 Survey: in 2011, 3% of respondents were single parents. The number of single-child families increased from 6% to 13%.

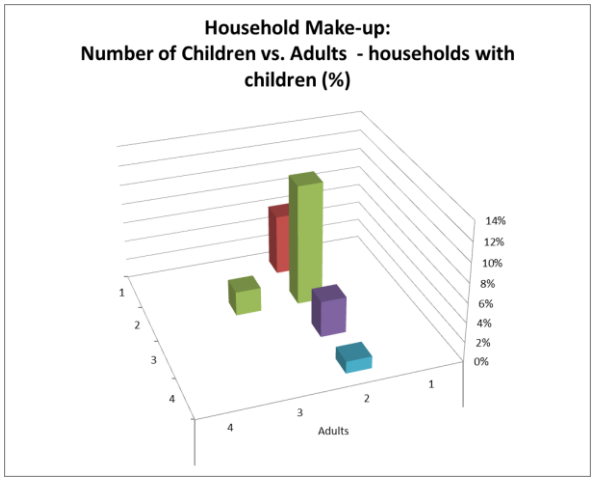


Figure 4-7 : Household make-up - households with children (%) - 2010 Survey

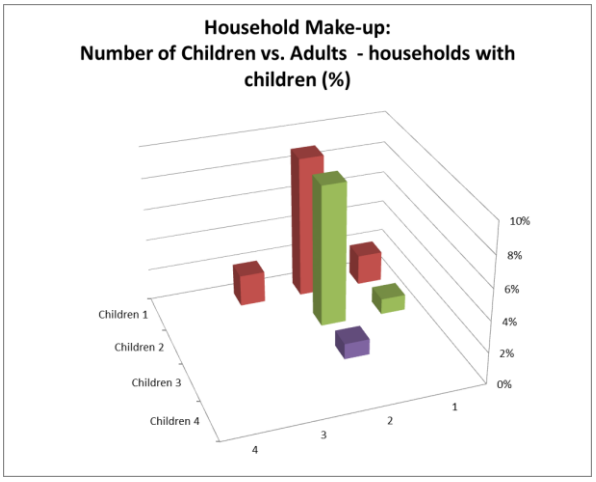


Figure 4-8 : Household make-up - households with children (%) - 2011 Survey

4.1.3 Ethnicity

The population of Lyttelton is predominantly European (> 80%). Māori represent a further ca. 10% (Statistics New Zealand 2006c), although they represented only 6% of the Survey 2010 sample. There is a small Asian community, and the rest are made up of other backgrounds: Middle-Eastern, African, Latin American, etc.

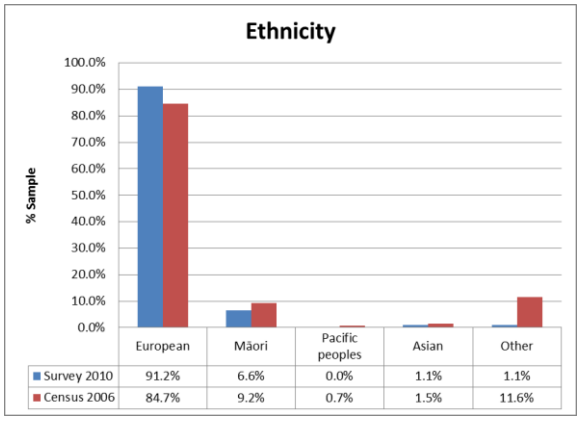


Figure 4-9 : Ethnicity of sample population - Survey 2010 vs. Census 2006

4.1.4 Income

The census questionnaire and the 2010 survey use two scales for income, so a direct comparison is not possible. However, based on the scatterplot (Figure 4-10) it is possible to observe that the 2010 survey has captured the long tail of the high income earners.

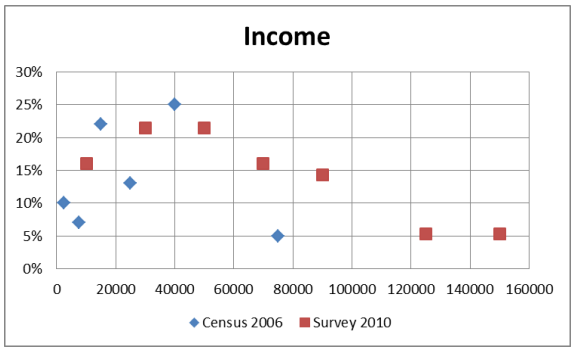


Figure 4-10 : Household income - Census 2006 vs. Survey 2010

4.1.5 Medical needs

10 (12.2%) of the 82 respondents in the 2010 survey reported having a condition requiring medication. 3 respondents were being treated at the time and had visits by their doctor to their home. There were no reported instances of household members being on life-support machinery, nor did anyone report requiring a constant water or electricity supply for medical reasons. Of the 9 replies that suggested they would require assistance in case of a disaster, 4 households noted this was because of help with young children, 4 were due to frailty, and one for help cleaning up.

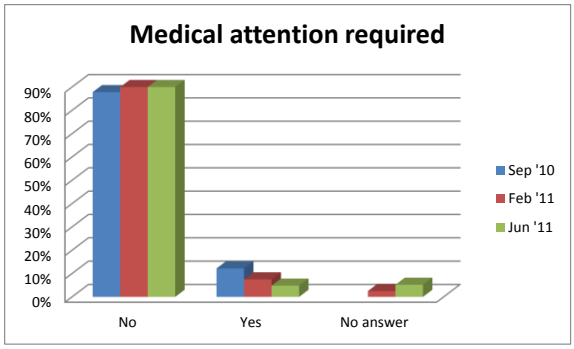


Figure 4-11 : Medical attention – September 2011, February 2011 and June 2011

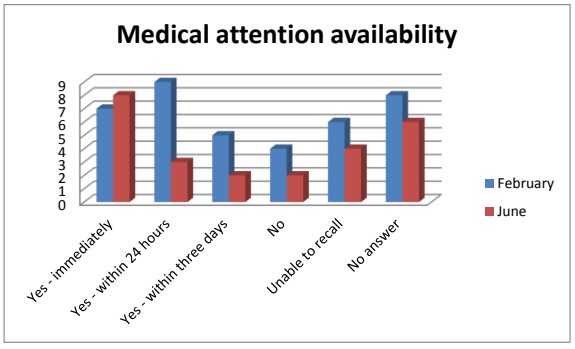


Figure 4-12 : Medical attention availability – September 2011, February 2011 and June 2011

4.1.6 Animals

In the 2010 survey, 57 (69.5%) of the 82 responding households reported having animals in their care: 57 (69.5%) with small animals (cats, dogs, birds); 3 (3.6%) also having larger animals or livestock; and, 3 (3.6%) also having chickens. 3 (3.6%) replies indicated very strongly that they would not leave their dog in any circumstance.

In the 2011 survey, 59% responding households reported having animals in their care in February, rising to 60% by June: 3% also reported having larger animals or livestock in both months.

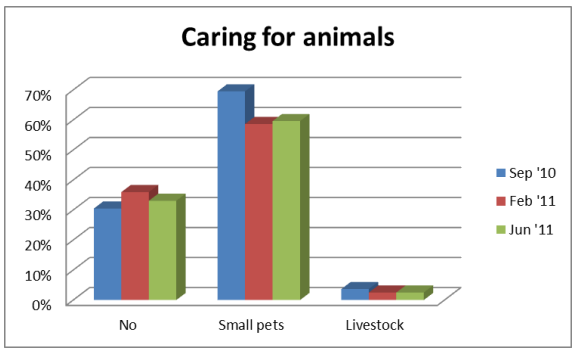


Figure 4-13 : Households with animals in their care

4.2 Population spatiotemporal distribution

The resident population moves without and outside of Lyttelton during the course of each day over a week. Two surveys were completed that studied this distribution over time and place.

4.2.1 Population spatiotemporal distribution survey (2010)

The written questionnaire in the 2010 survey asked respondents to record the location and activity throughout a typical week for up to 4 significant household members.

The weekly schedule was divided into 7 days each of 6 three-hour segments spanning 06:00 – 00:00, and one six-hour segment between 00:00 and 06:00. The assumptions for deciding this particular segmentation are as follows:

00:00 – 06:00	Most people would not have a separate activity between 00:00 – 03:00 and 03:00 – 06:00.
06:00 – 09:00	Most people would be waking up and getting ready for work or school.
09:00 – 12:00	General morning period, to coincide with morning school.
12:00 – 15:00	General afternoon period, to coincide with afternoon school.
15:00 – 18:00	After school, late worker, or returning home.
18:00 – 21:00	Evening meal or evening activity.
21:00 – 24:00	It is assumed that most people would be at home, but some would be at work or be relaxing outside of the home.

Each respondent (as many as four per household) was requested to populate every daily segment according to the following key:

- H – Home
- W – Work
- E – Education
- S – Shopping
- R – Recreation

After the questionnaire was returned it was found necessary to code a sixth activity: V for variable. Some people were on shift work and the model as defined would not be able to accommodate them. Rather than show the schedule as blank it was filled in as a Variable schedule and treated for this analysis as being at home.

The data points of interest were when the individual was at home (H), or indicated a variable (V) schedule.

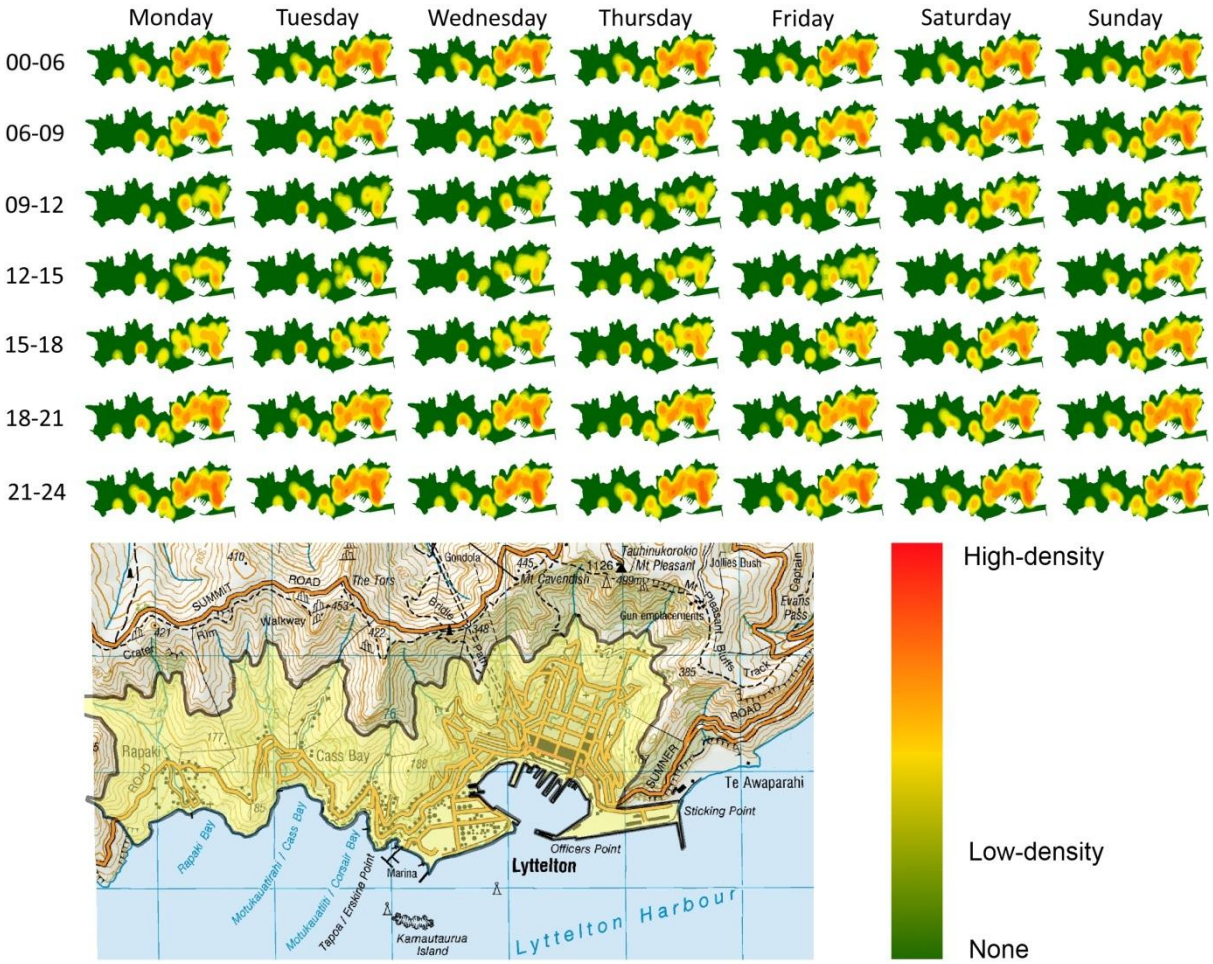


Figure 4-14 : Population density of study area population over a complete week, pre-September 2010

4.2.2 Vehicle Proxy Census

The vehicle proxy data was imported into Esri ArcGIS and analysed using the kernel density tool. The analysis was carried out in triplicate, once for each day of the census.

The data was further normalised to allow comparison of the density and the colour ramp chosen to show dense vehicle distributions as red and low distribution as green (Figure 4-17).

It can be seen that during the daytime (Mondays and Sundays) there is a higher density of vehicles parked in the central town along London Street. This is a popular destination during weekends for day-trippers and on Mondays for workers and residents getting a bite to eat or doing shopping.

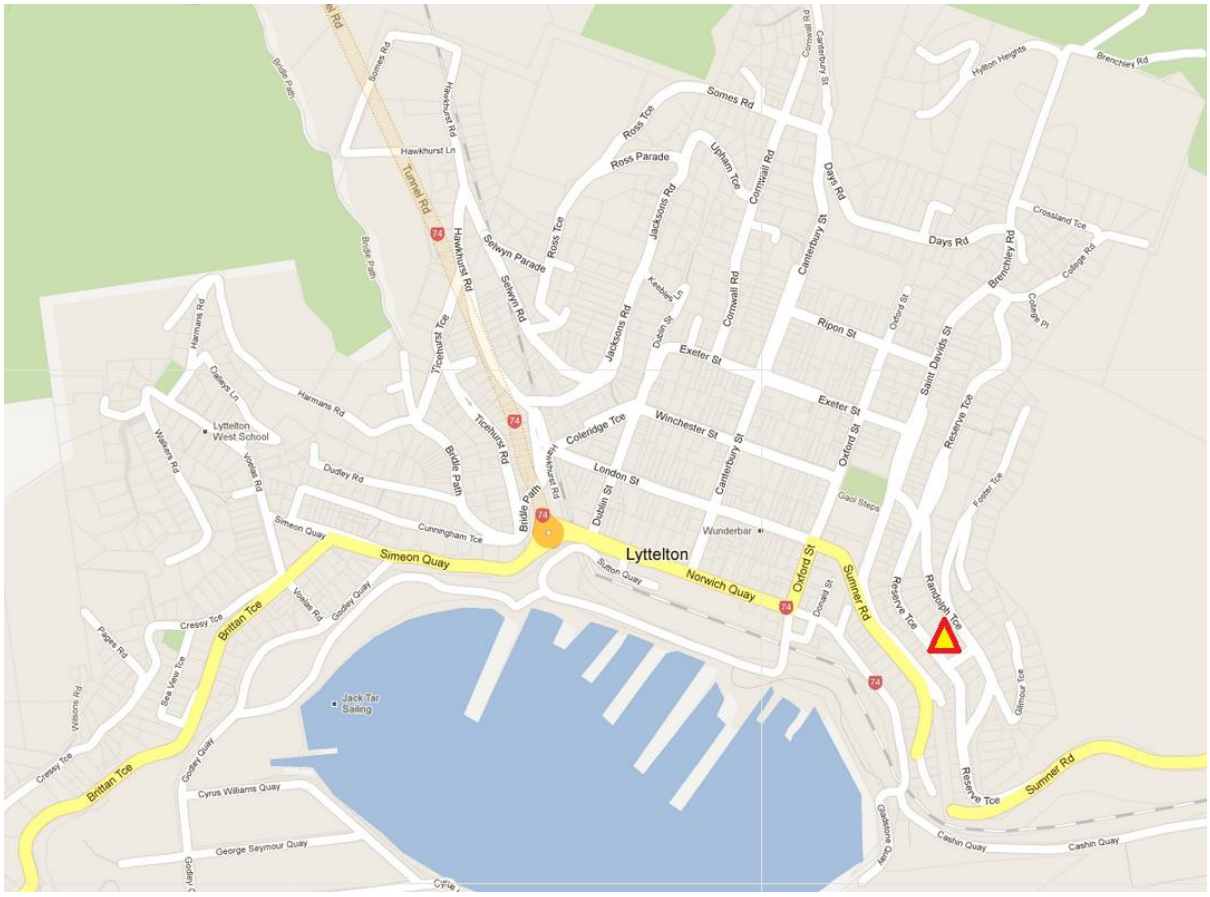


Figure 4-15 : Road map of Lyttelton

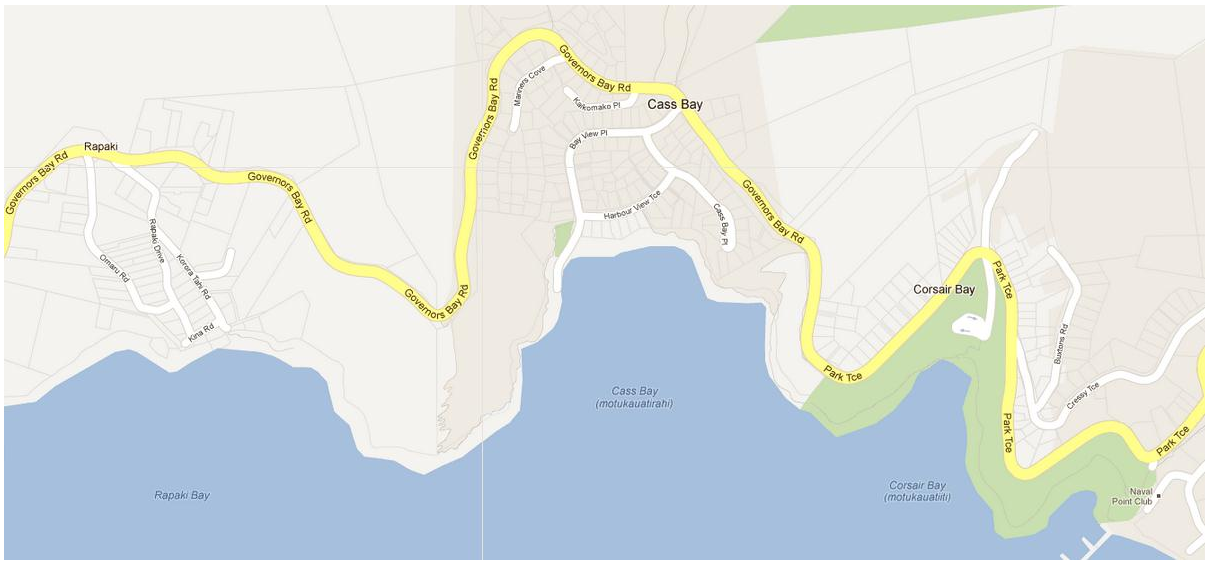


Figure 4-16 : Road map of Rapaki, Cass Bay, and Corsair Bay

On Wednesdays, the density changed to reflect the higher number of people returning home. A dense area on Winchester Street shows the high number of vehicles parked outside the recreation centre.

On the particular Sundays the data was collected, the study detected a high density of vehicles on Reserve Terrace (marked with a triangle - Figure 4-15) due to a popular party being held.

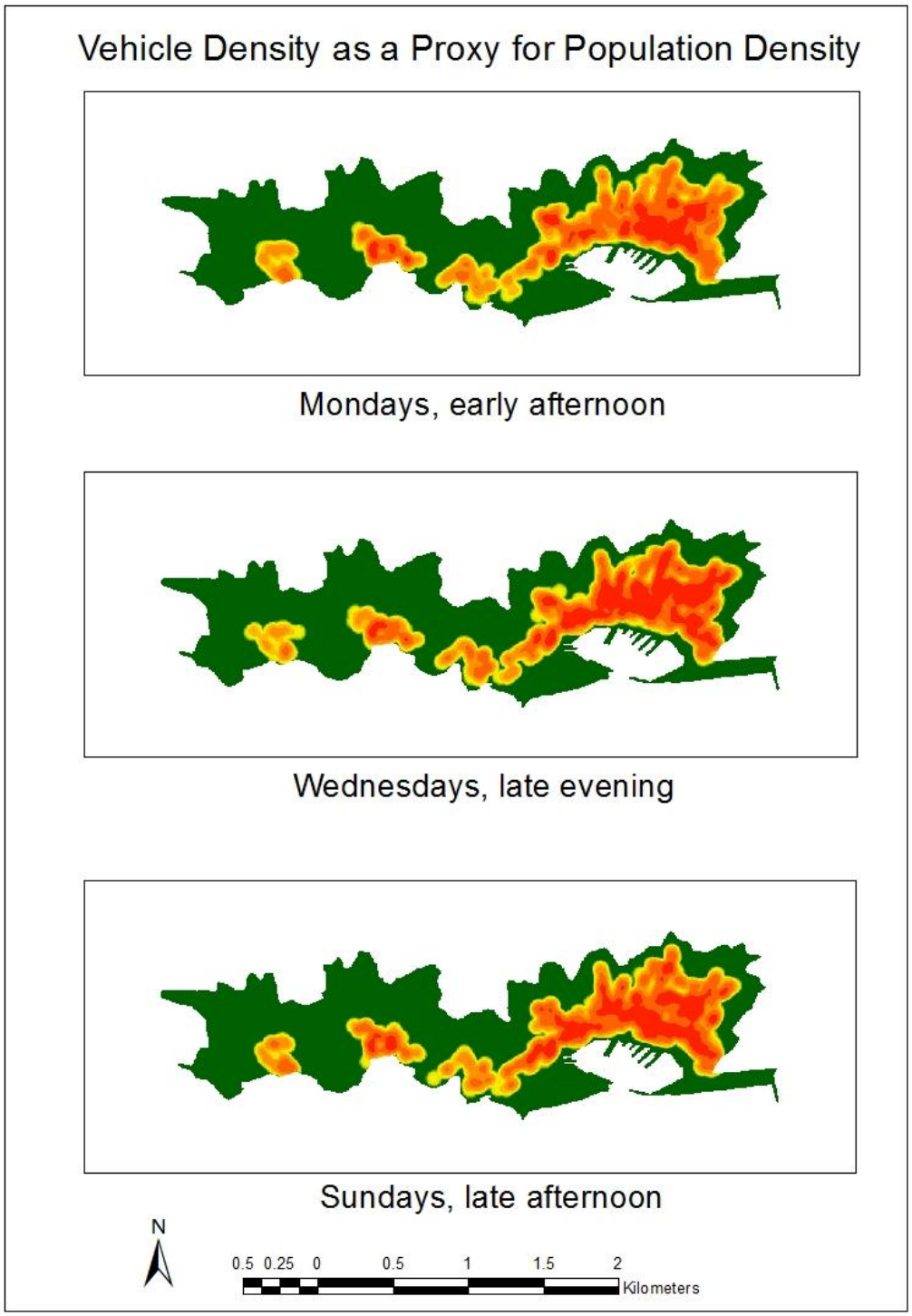


Figure 4-17 : Lyttelton mid-2010 parked vehicle census as proxy for population distribution

4.3 Vulnerability

Vulnerability refers to the potential for casualty, destruction, damage, disruption or other forms of loss in a particular element (Alexander 2000).

4.3.1 Deprivation index

The Atlas of Socioeconomic Deprivation in New Zealand NZDep2006 (White et al. 2008) describes the deprivation experienced by groups of people in small areas. It is created from data from the Statistics New Zealand 2006 Census of Population and Dwellings (Statistics New Zealand 2006a).

It is mainly used as a tool to determine funding levels in certain areas for health and social services, but increasingly is used as a measure or proxy for other purposes (e.g. vulnerability for CDEM purposes) (Daly 2009).

The index is constructed from nine variables, reflecting eight types of deprivation. The variables, in decreasing importance in NZDep2006, are summarised in Table 4-1.

Table 4-1 : Description of the nine variables, in decreasing importance, used to construct the New Zealand Index of Deprivation 2006

Deprivation domain	Census variable
Income	Aged 18-64 years receiving a means-tested benefit
Income	Living in households with equivalised income below an income threshold
Owned home	Not living in own home
Support	Aged under 65 years living in a single-parent family
Employment	Aged 18-64 years and unemployed
Qualifications	Aged 18-64 years and without any qualifications
Living space	Living in households below an equivalised bedroom occupancy threshold
Communication	With no access to a telephone
Transport	With no access to a car

The deprivation index is a number ranging from 1 to 10. 1 represents the least deprived 10% of the population of New Zealand and 10 represents the most deprived 10% of the population.

Lyttelton exhibits a small core of very high deprivation (Deprivation index = 9) centred on the west end of London Street. This area is a mixture of residential property, retirement flats, light engineering and industry, the recreation centre, and the Lyttelton Club and Four Ships Restaurant complex. Two blocks to the North of London Street is another high deprivation centre (Deprivation index = 7), bounded by Canterbury Street, Winchester Street, Oxford Street, and Ripon Street. This area is a mixture of residential property, retirement flats, and churches and associated properties.

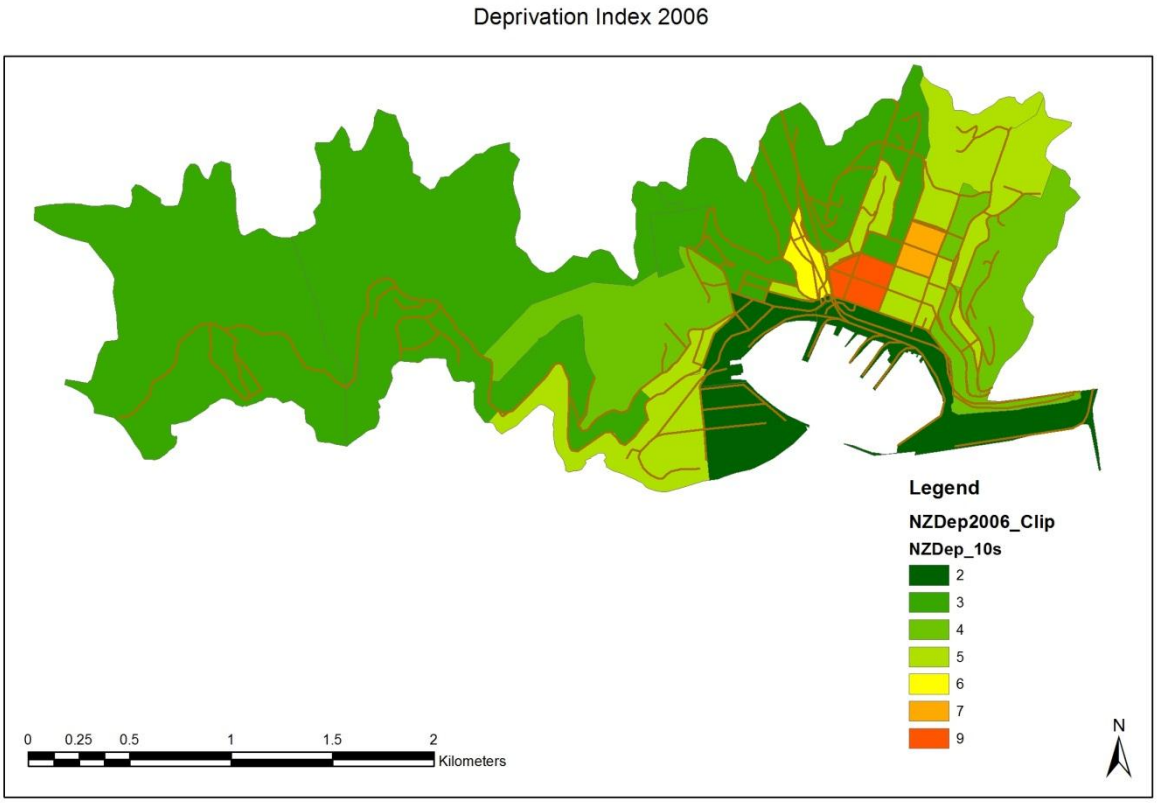
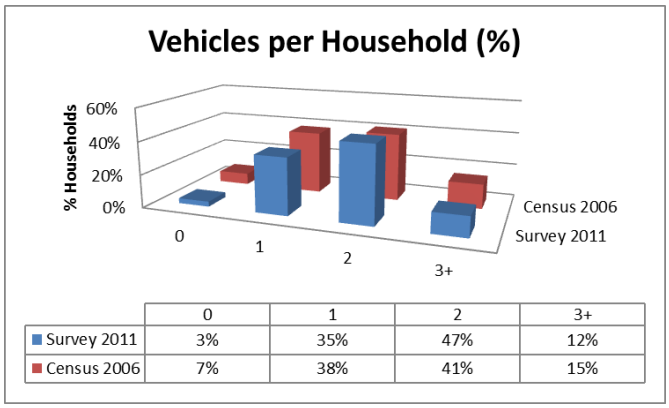


Figure 4-18 : Deprivation Index map for Lyttelton and surrounding areas - from (White et al. 2008)

4.3.2 Access to transport

The 2011 survey identified 935 vehicles (excluding motorcycles) at the 520 households participating in the study (Figure 4-19).

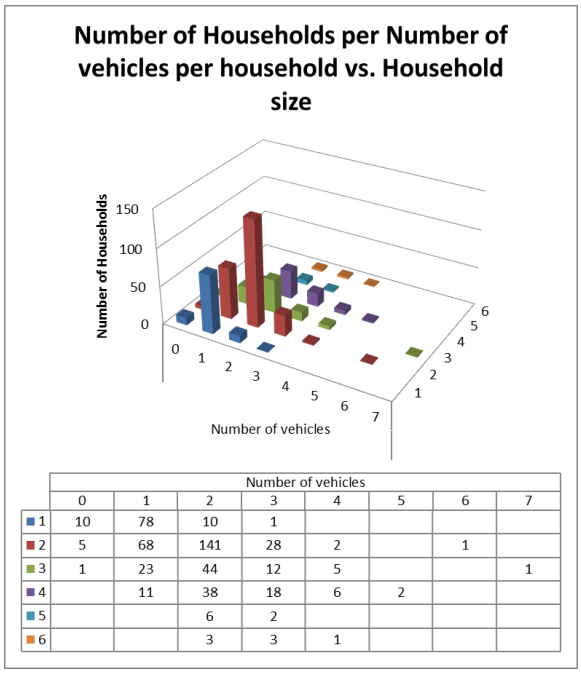


	0	1	2	3+
Survey 2011	3%	35%	47%	12%
Census 2006	7%	38%	41%	15%

Figure 4-19 : Vehicles per Household (% of households) - Census 2006 vs. Survey 2011

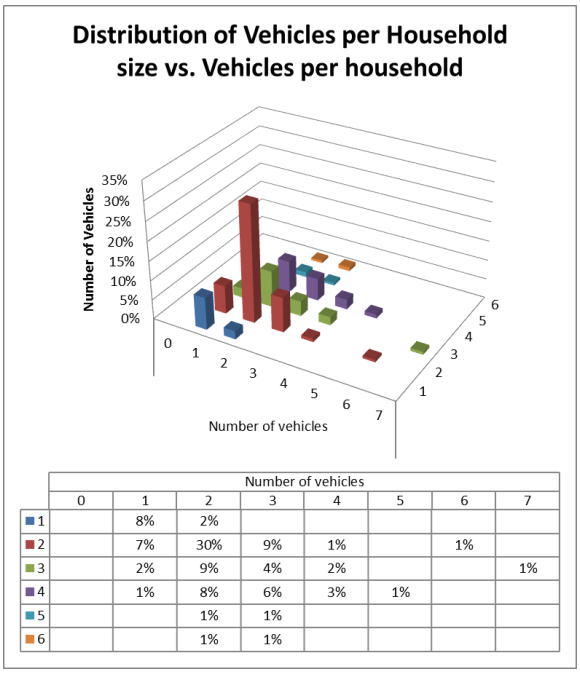
Further analysis of the 2011 Survey results shows the predominant ownership of vehicles comes from 2-person households, who own 2 vehicles (Figure 4-20). This is reflected in the

analysis of how the vehicles are distributed between households, showing two-person two-vehicle households own 30% of the whole vehicle fleet (Figure 4-21).



	Number of vehicles							
	0	1	2	3	4	5	6	7
1	10	78	10	1				
2	5	68	141	28	2		1	
3	1	23	44	12	5			1
4		11	38	18	6	2		
5			6	2				
6			3	3	1			

Figure 4-20 : Number of Households per Number of vehicles per household vs. Household size - Survey 2011



	Number of vehicles							
	0	1	2	3	4	5	6	7
1		8%	2%					
2		7%	30%	9%	1%		1%	
3		2%	9%	4%	2%			1%
4		1%	8%	6%	3%	1%		
5			1%	1%				
6			1%	1%				

Figure 4-21 : Distribution of Vehicles per Household size vs. Vehicles per household – Survey 2011

Access to private transport became very important after the Christchurch Earthquake as public transport services were shut down. Not having access to transport would increase the household vulnerability to losing work if unable to get to it, financial penalties if they had to pay for a taxi, and loss of mobility.

4.3.3 Building stock

Prior to the Darfield Earthquake, the town of Lyttelton was a gem of historical and heritage buildings (Burgess 2009b). A large part of the town was considered to be of heritage status, retaining the context of the early settler years, with the preponderance of 19th century homes (see Figure 4-22) being what made Lyttelton Lyttelton.

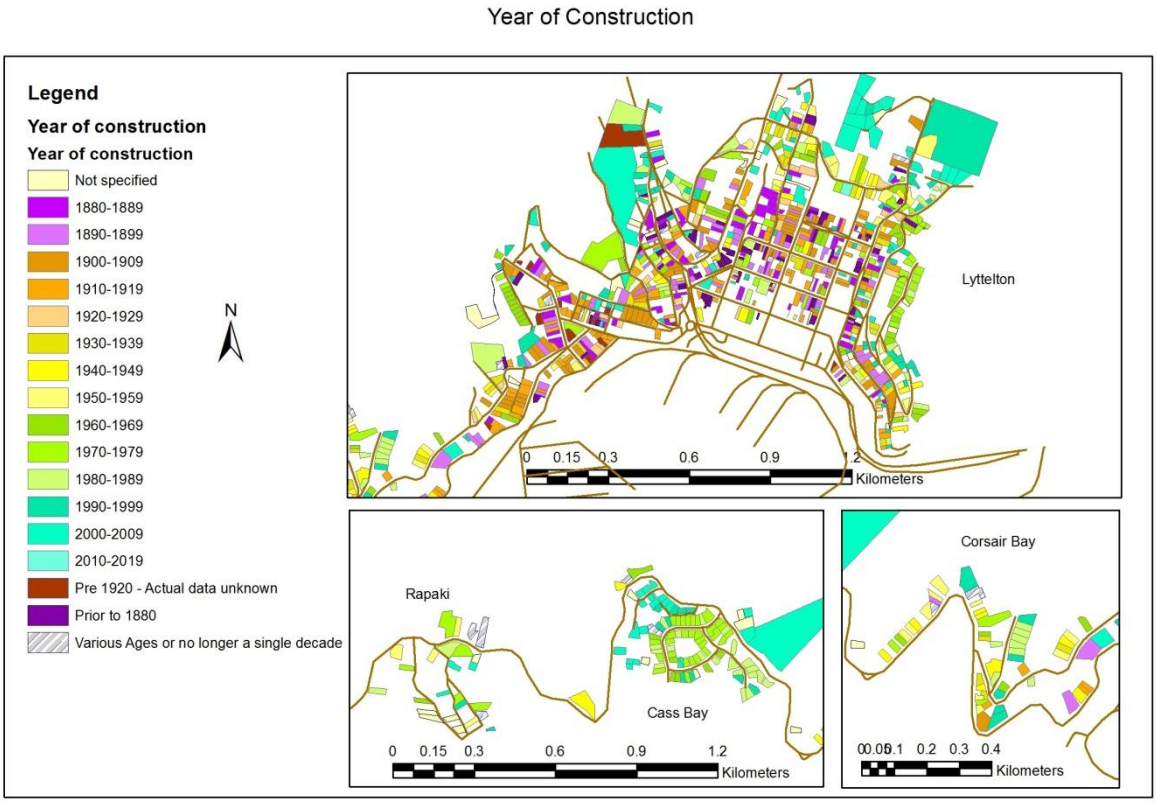


Figure 4-22 : Year of construction for buildings in Lyttelton and surrounding area

Unreinforced masonry was prevalent in the built landscape (Figure 4-23), especially for chimneys, which played a role in the felling and holing of a few chimneys and roofs after the Darfield Earthquake. It may have been good fortune that the Darfield Earthquake felled a number of chimneys in September. The Christchurch and Sumner earthquakes played a major role in casting the architectural heritage of the town to the ground, among them all of the stone churches and one of the still operational Timeball stations in the world that Lyttelton was famous for.

Many timber buildings also suffered damage, but luckily there were no fires unlike after the 1995 M_w 6.9 Kobe or the 1906 M_w 7.9 San Francisco Earthquakes. Things may have been a lot worse had the Darfield and Christchurch Earthquakes not occurred, as people would

most likely have been heating their homes using log burners come June.

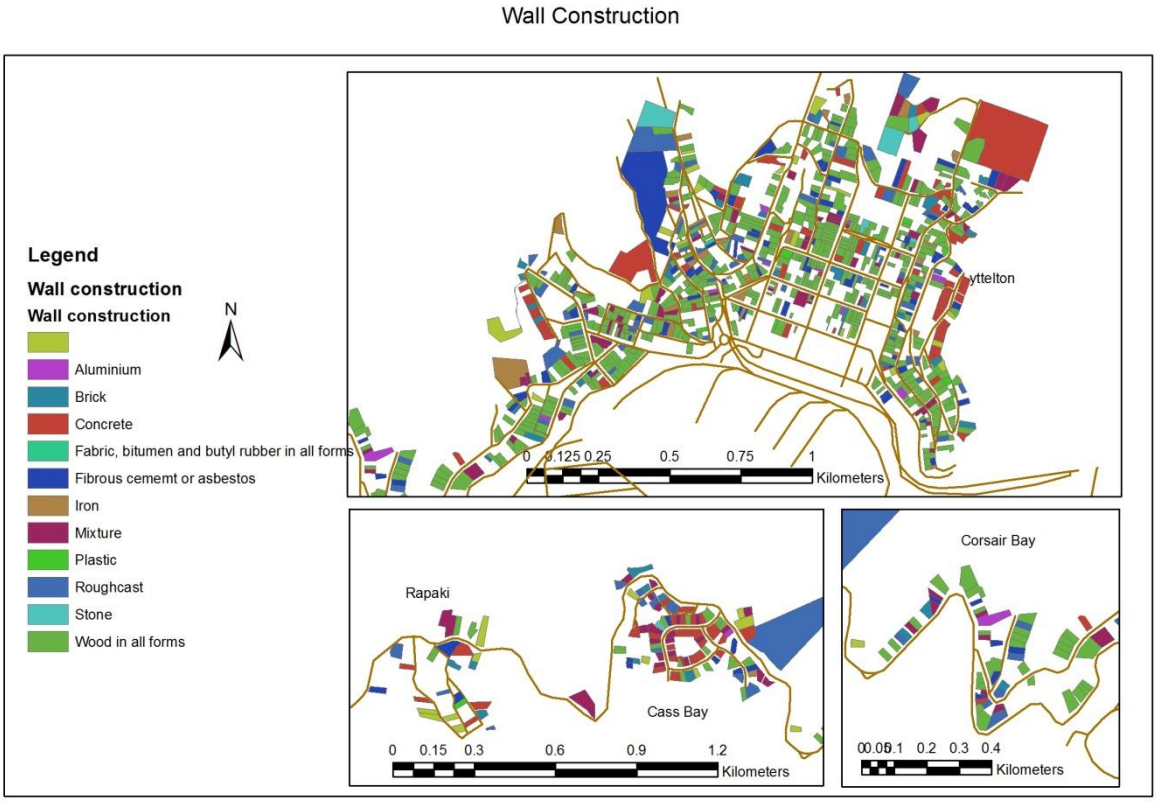


Figure 4-23 : Wall construction type for buildings in Lyttelton and surrounding areas

4.4 Discussion

Other than a few small pockets, Lyttelton residents are in the least-deprived half of the population with respect to deprivation. The population consists of a well-mixed cross-section through New Zealand society, with little evidence of discrimination against minorities.

Help for those in need came from the community rather than from a government-directed source:

> *"During the recent earthquake 4/09/10 there seemed to be no CD here in Lyttelton. However the Lyttelton Time Bank took over that role & did a great job." – Reply from 2010 Survey*

> *"The Lyttelton Civil Defence Post did not open on the morning of the earthquake. It should have been. Several people went but nobody was there." – Reply from 2010 Survey*

"Support after Feb was excellent, water, Navy, Red Cross etc. / After June, nothing." – Reply from 2011 Survey

Community groups, such as the Project Lyttelton and Time Bank, play a strong role in the community.

Many households are families with children, and many have animals in their care. There is concern that children are vulnerable, especially when at school and their parents at work, perhaps on the other side of the tunnel.

Many of the vulnerable buildings in Lyttelton have collapsed, are being demolished, or are in the process of being supported ready for a possible rebuild to higher standards. There is little land left in Lyttelton for new subdivisions to be built on. New subdivisions are encroaching on the land adjacent to the reserves running above Lyttelton, but that leaves them exposed to rockfall hazard and possible mass movement or landslide hazard. The alternative would be to remove an existing or demolished building, remediate the land, and replace with a new, stronger building, but being a town of exceptional heritage character, this would prove time-consuming and expensive to accommodate.

The 2011 Survey found 16 households (23 individuals) which did not have their own private vehicle. This could make them vulnerable in case they chose to evacuate, or if they were dependent on public transport to get them to work they could lose their job. It is likely that they would find other transport alternatives, for instance with neighbours, but if they relied on the bus to take them and a bicycle through the tunnel, they would be disadvantaged.

Although following the major events affecting Lyttelton some employment sectors typically experience increased activity (e.g. construction, Lyttelton Port), many sources of employment and income were disrupted following the Christchurch Earthquake. This increased the financial vulnerability of those households with a higher Deprivation Index.

5 Preparedness of the households

5.1 Pre-Darfield Earthquake vs. Post-Sumner Earthquakes

The 2010 and 2011 surveys carried similar questions regarding preparedness, allowing comparisons to be made.

5.1.1 Household inventory comparison – 2010 vs. 2011

Most households replying to the 2010 survey had some form of provisions that could be accessed during an emergency. Most households replying to the 2011 survey also had some form of provisions; however, the proportional mix had changed[3] (Figure 5-1).

[3] The 2010 survey did not include the data points for "Tent or other portable shelter" or "Cash".

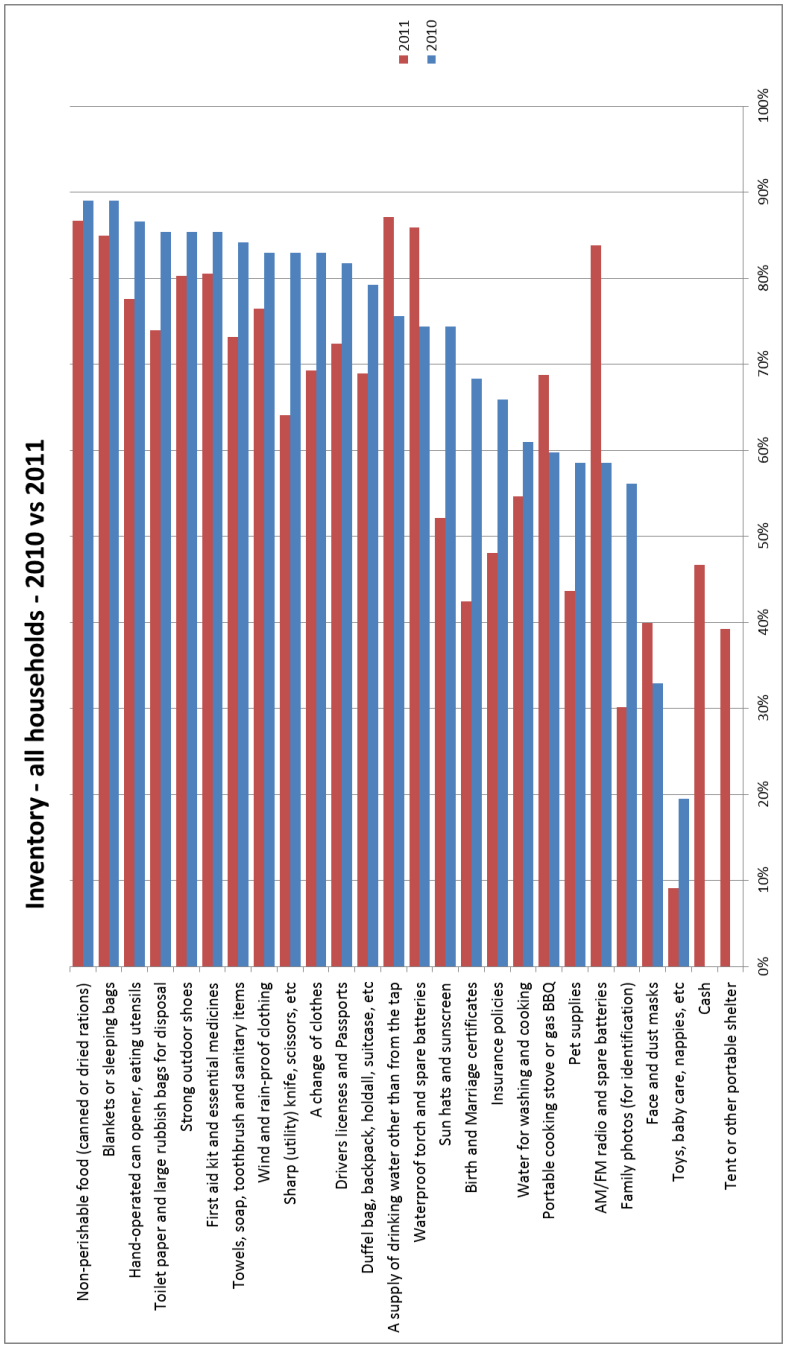


Figure 5-1 : Emergency household provisions, across all household (with and without children) - 2010 vs. 2011

Table 5-1 : Emergency household provisions, across all household (with and without children) - 2010 vs. 2011

All households	2010	2011
Blankets or sleeping bags	89%	85%
Non-perishable food (canned or dried rations)	89%	87%
Hand-operated can opener, eating utensils	87%	78%
First aid kit and essential medicines	85%	81%
Strong outdoor shoes	85%	80%
Toilet paper and large rubbish bags for disposal	85%	74%
Towels, soap, toothbrush and sanitary items	84%	73%
A change of clothes	83%	69%
Sharp (utility) knife, scissors, etc.	83%	64%
Wind and rain-proof clothing	83%	76%
Drivers licenses and Passports	82%	72%
Duffel bag, backpack, holdall, suitcase, etc.	79%	69%
A supply of drinking water other than from the tap	76%	87%
Sun hats and sunscreen	74%	52%
Waterproof torch and spare batteries	74%	86%
Birth and Marriage certificates	68%	42%
Insurance policies	66%	48%
Water for washing and cooking	61%	55%
Portable cooking stove or gas BBQ	60%	69%
AM/FM radio and spare batteries	59%	84%
Pet supplies	59%	44%
Family photos (for identification)	56%	30%
Face and dust masks	33%	40%
Toys, baby care, nappies, etc.	20%	9%
Tent or other portable shelter	0%[3]	39%
Cash	0%[3]	47%

Of particular interest is the rise between 2010 and 2011 of the percentage of households with drinking water storage, torch, portable cooking stove, battery-powered AM/FM radio, and dust masks. This suggests the direct effects of the Darfield Earthquake on the study area population, as well as media reporting of the Christchurch Eastern suburbs that were heavily affected by liquefaction, which may have directly or indirectly informed people to stock up on certain items (Table 5-2):

Table 5-2 : Possible reasons for households stocking up on certain provisions

Item	Possible reason
Drinking water	Failure of reticulated water supply
Torch	The Darfield Earthquake struck in the early hours when it was still dark
Portable cooking stove	Failure of electricity supply, kitchen in home not usable
Battery-powered radio	Seeking information and entertainment
Dust masks	Dust caused by liquefaction and winds

The results of all samples were further decomposed into households with and without children and a comparison made.

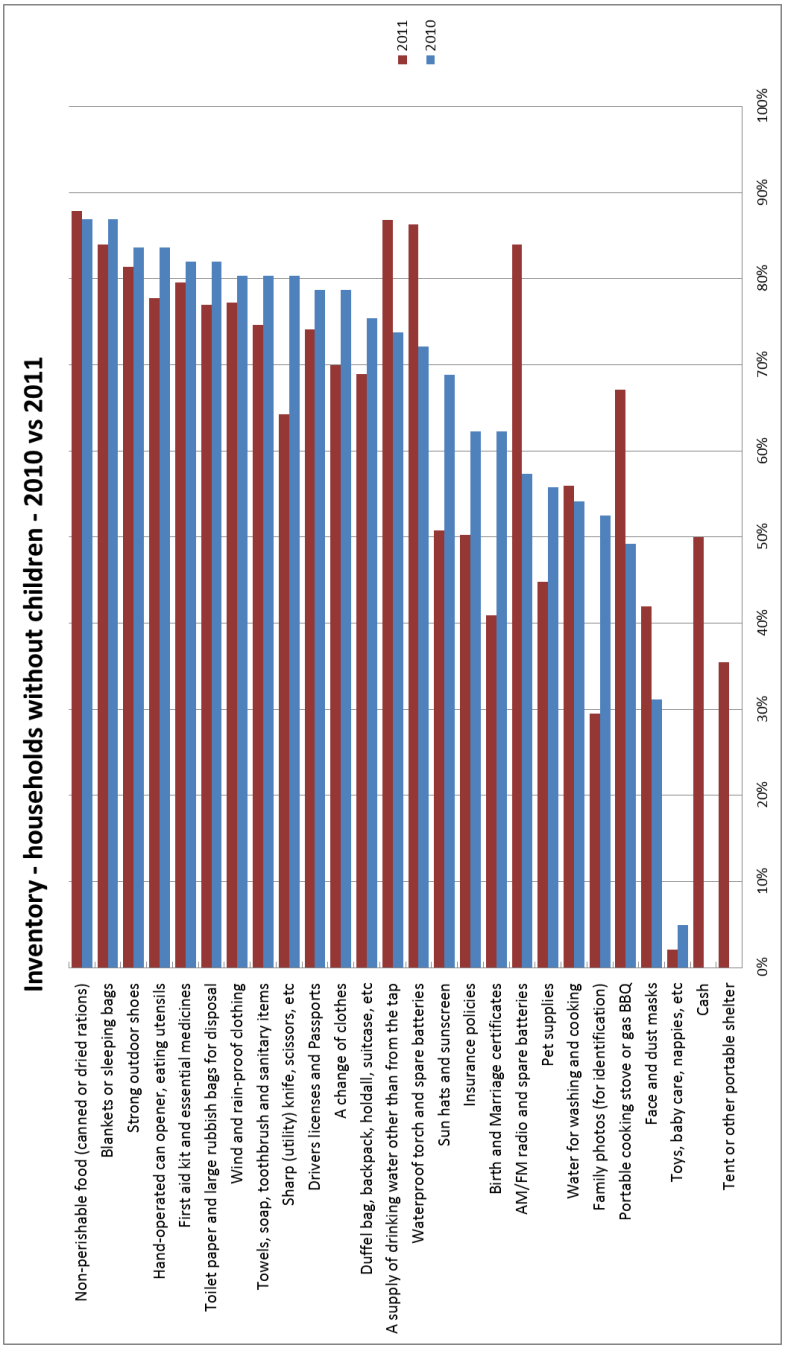


Figure 5-2 : Inventory - Households without children - 2010 vs. 2011

Table 5-3 : Inventory - Households without children - 2010 vs. 2011

Households with no children	2010	2011
Blankets or sleeping bags	87%	84%
Non-perishable food (canned or dried rations)	87%	88%
Hand-operated can opener, eating utensils	84%	78%
Strong outdoor shoes	84%	81%
Toilet paper and large rubbish bags for disposal	82%	77%
First aid kit and essential medicines	82%	80%
Sharp (utility) knife, scissors, etc.	80%	64%
Towels, soap, toothbrush and sanitary items	80%	75%
Wind and rain-proof clothing	80%	77%
A change of clothes	79%	70%
Drivers licenses and Passports	79%	74%
Duffel bag, backpack, holdall, suitcase, etc.	75%	69%
A supply of drinking water other than from the tap	74%	87%
Waterproof torch and spare batteries	72%	86%
Sun hats and sunscreen	69%	51%
Birth and Marriage certificates	62%	41%
Insurance policies	62%	50%
AM/FM radio and spare batteries	57%	84%
Pet supplies	56%	45%
Water for washing and cooking	54%	56%
Family photos (for identification)	52%	30%
Portable cooking stove or gas BBQ	49%	67%
Face and dust masks	31%	42%
Toys, baby care, nappies, etc.	5%	2%
Tent or other portable shelter	0%	35%
Cash	0%	50%

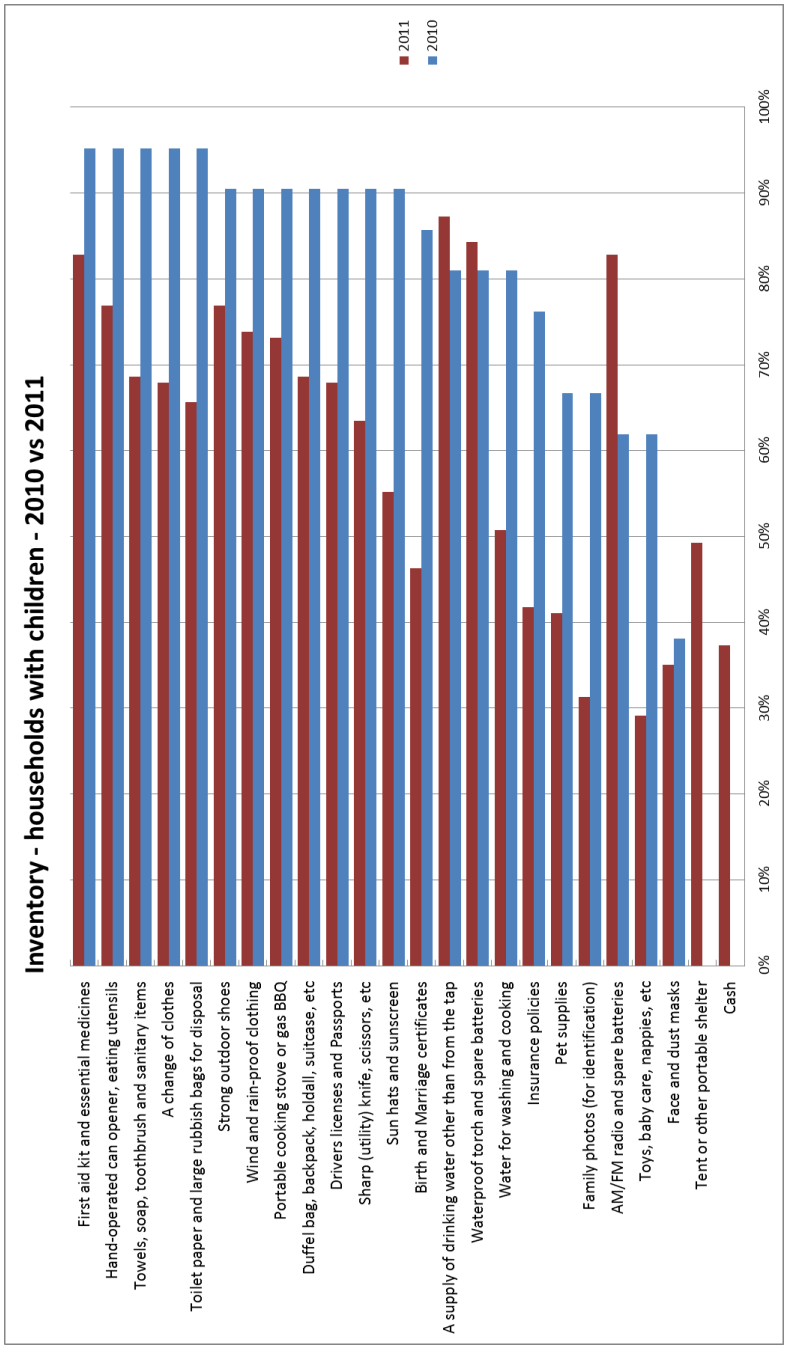


Figure 5-3 : Inventory - Households with children - 2010 vs. 2011

Table 5-4 : Inventory - Households with children - 2010 vs. 2011

Household with children	2010	2011
Toilet paper and large rubbish bags for disposal	95%	66%
A change of clothes	95%	68%
Towels, soap, toothbrush and sanitary items	95%	69%
Hand-operated can opener, eating utensils	95%	77%
First aid kit and essential medicines	95%	83%
Non-perishable food (canned or dried rations)	95%	84%
Blankets or sleeping bags	95%	87%
Sun hats and sunscreen	90%	55%
Sharp (utility) knife, scissors, etc.	90%	63%
Drivers licenses and Passports	90%	68%
Duffel bag, backpack, holdall, suitcase, etc.	90%	69%
Portable cooking stove or gas BBQ	90%	73%
Wind and rain-proof clothing	90%	74%
Strong outdoor shoes	90%	77%
Birth and Marriage certificates	86%	46%
Water for washing and cooking	81%	51%
Waterproof torch and spare batteries	81%	84%
A supply of drinking water other than from the tap	81%	87%
Insurance policies	76%	42%
Family photos (for identification)	67%	31%
Pet supplies	67%	41%
Toys, baby care, nappies, etc.	62%	29%
AM/FM radio and spare batteries	62%	83%
Face and dust masks	38%	35%
Cash	0%	37%
Tent or other portable shelter	0%	49%

5.1.2 Household inventory comparison – with vs. without children

Before the Darfield Earthquake the households with children were considerably better-stocked than those without.

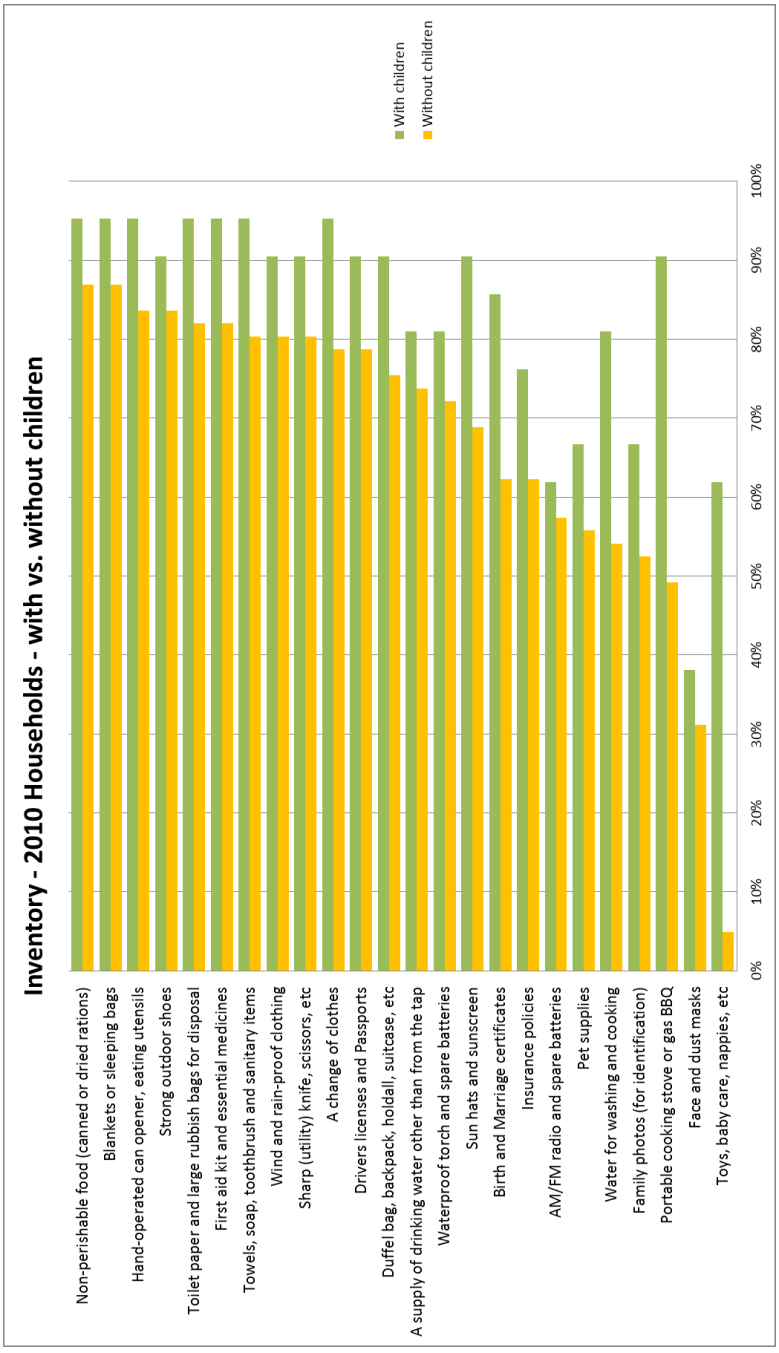


Figure 5-4 : Inventory - 2010 Households - with vs. without children

Table 5-5 : Inventory - 2010 Households - with vs. without children

2010 Households	Without children	With children
Blankets or sleeping bags	87%	95%
Non-perishable food (canned or dried rations)	87%	95%
Hand-operated can opener, eating utensils	84%	95%
Strong outdoor shoes	84%	90%
First aid kit and essential medicines	82%	95%
Toilet paper and large rubbish bags for disposal	82%	95%
Towels, soap, toothbrush and sanitary items	80%	95%
Sharp (utility) knife, scissors, etc.	80%	90%
Wind and rain-proof clothing	80%	90%
A change of clothes	79%	95%
Drivers licenses and Passports	79%	90%
Duffel bag, backpack, holdall, suitcase, etc.	75%	90%
A supply of drinking water other than from the tap	74%	81%
Waterproof torch and spare batteries	72%	81%
Sun hats and sunscreen	69%	90%
Birth and Marriage certificates	62%	86%
Insurance policies	62%	76%
AM/FM radio and spare batteries	57%	62%
Pet supplies	56%	67%
Water for washing and cooking	54%	81%
Family photos (for identification)	52%	67%
Portable cooking stove or gas BBQ	49%	90%
Face and dust masks	31%	38%
Toys, baby care, nappies, etc.	5%	62%
Cash	0%	0%
Tent or other portable shelter	0%	0%

By July 2011, the situation had changed markedly, with households with children being less prepared on average than those without in most provisions listed. This could be explained by those without children purchasing more inventory after the Darfield Earthquake to make them more prepared than those with children.

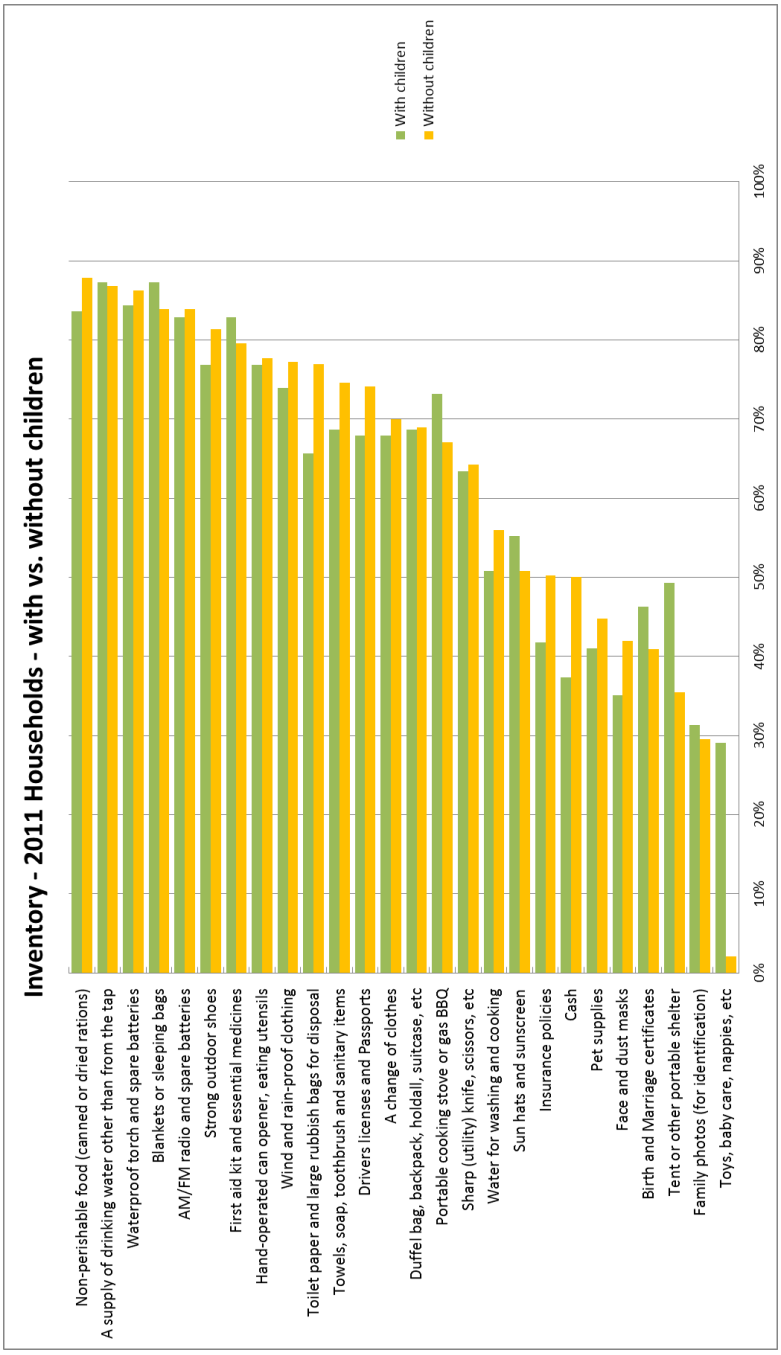


Figure 5-5 : Inventory - 2011 Households - with vs. without children

Table 5-6 : Inventory - 2011 Households - with vs. without children

2011 Households	Without children	With children
Non-perishable food (canned or dried rations)	88%	84%
A supply of drinking water other than from the tap	87%	87%
Waterproof torch and spare batteries	86%	84%
AM/FM radio and spare batteries	84%	83%
Blankets or sleeping bags	84%	87%
Strong outdoor shoes	81%	77%
First aid kit and essential medicines	80%	83%
Hand-operated can opener, eating utensils	78%	77%
Wind and rain-proof clothing	77%	74%
Toilet paper and large rubbish bags for disposal	77%	66%
Towels, soap, toothbrush and sanitary items	75%	69%
Drivers licenses and Passports	74%	68%
A change of clothes	70%	68%
Duffel bag, backpack, holdall, suitcase, etc.	69%	69%
Portable cooking stove or gas BBQ	67%	73%
Sharp (utility) knife, scissors, etc.	64%	63%
Water for washing and cooking	56%	51%
Sun hats and sunscreen	51%	55%
Insurance policies	50%	42%
Cash	50%	37%
Pet supplies	45%	41%
Face and dust masks	42%	35%
Birth and Marriage certificates	41%	46%
Tent or other portable shelter	35%	49%
Family photos (for identification)	30%	31%
Toys, baby care, nappies, etc.	2%	29%

5.1.3 Household inventory comparison - 2011 Survey vs. Deprivation Index 2006

An analysis of the inventory as of July 2011 against the Deprivation Index 2006 of each household was performed. A visualisation of the results is shown in Figure 5-6.

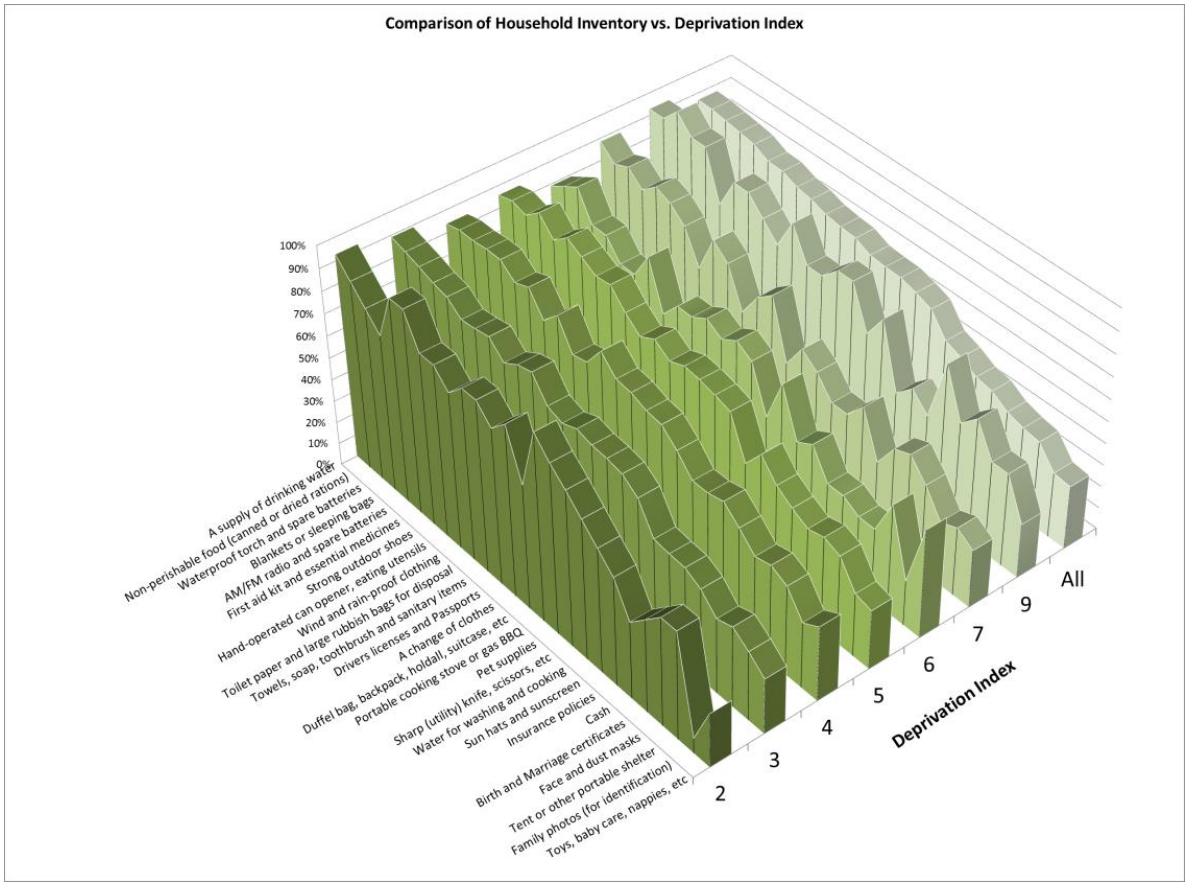


Figure 5-6 : Comparison of household inventory in July 2011 vs. Deprivation Index 2006

The individual inventory items are further decomposed and ordered to allow comparison between the households of normalised Deprivation Index, plus the percentage of all households.

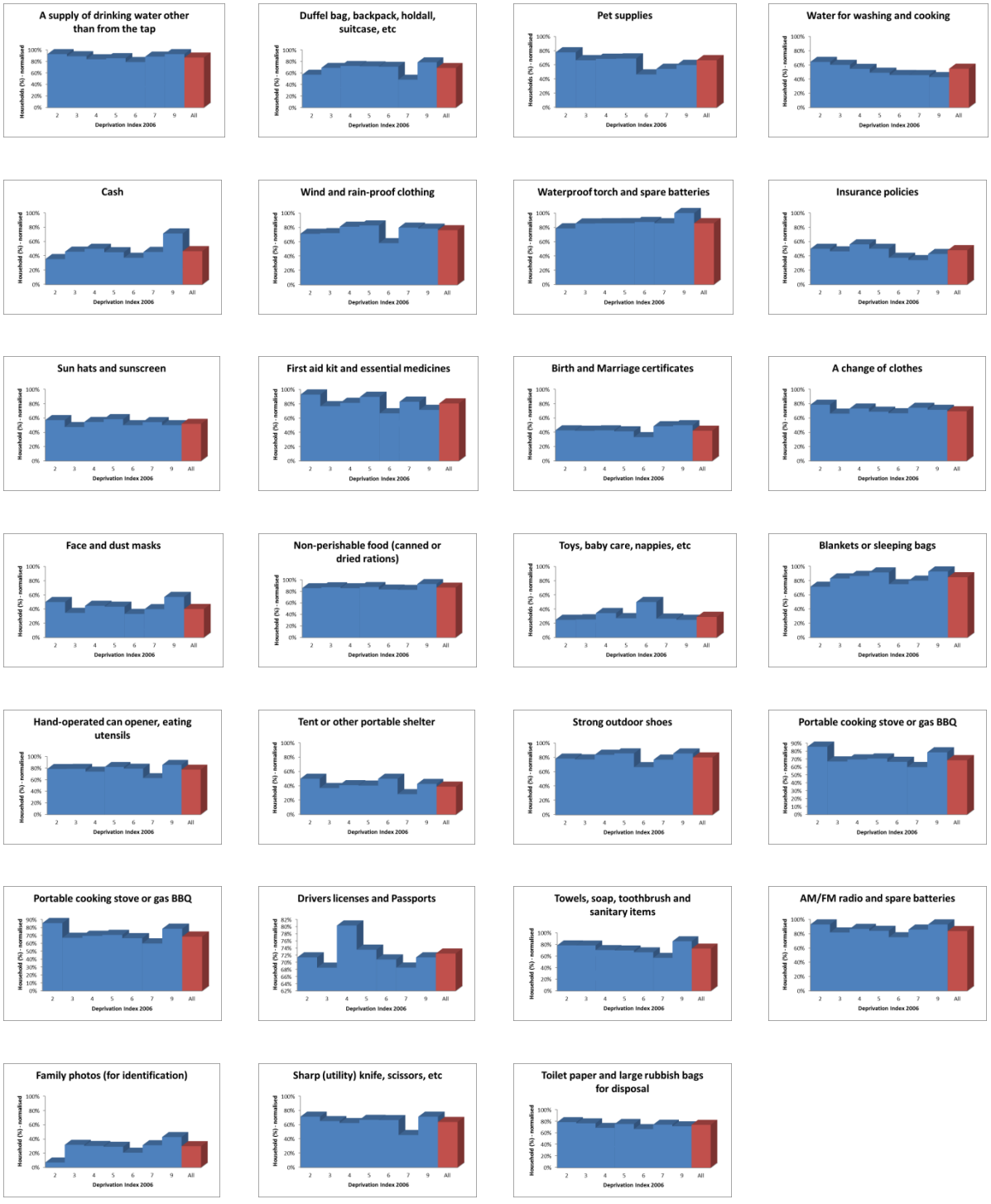


Figure 5-7 : Individual inventory items vs. uptake in households per Deprivation Index

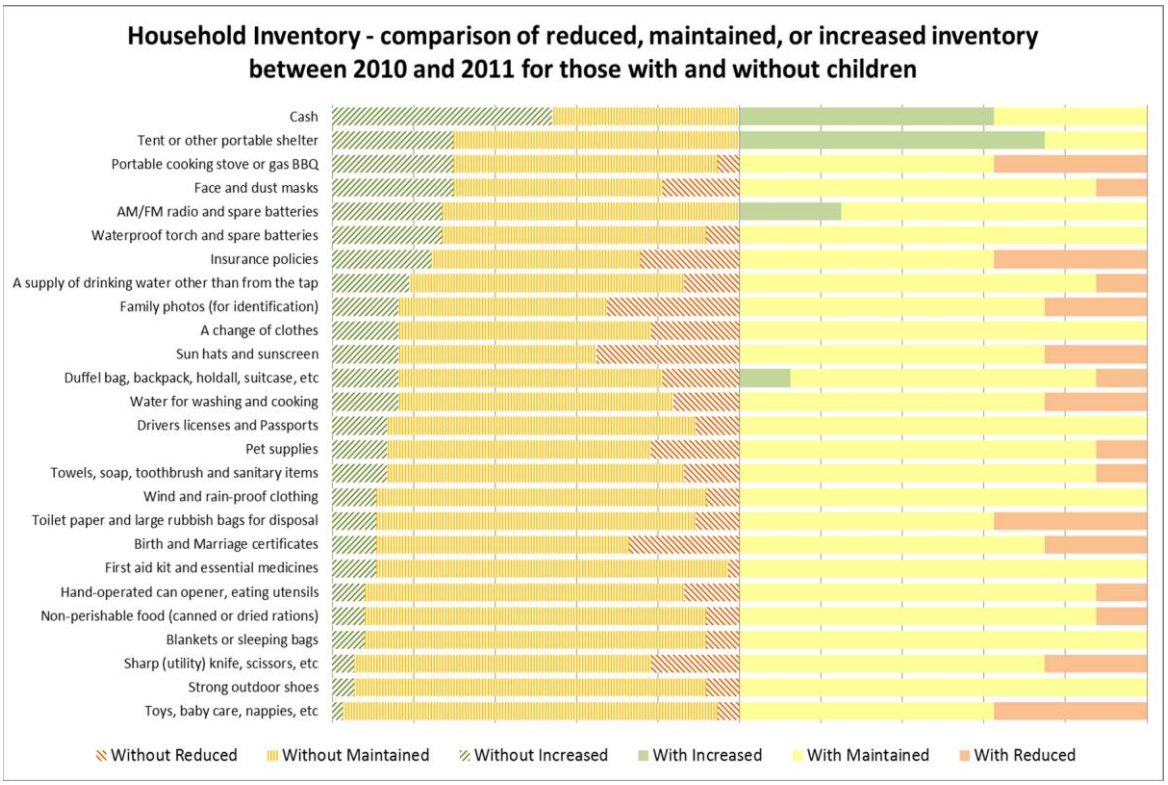
5.1.4 Longitudinal study

Of the 50 households identified as being in common between the 2010 and 2011 surveys, 37 were households not having children and 8 had children. A further 5 households were

identified where the number of children was reported as being zero in one sample and non-zero in the other.

Comparison of the inventory movement in these households (Figure 5-8) reveals that all categories increased in households without children in general, whereas only radios and travel bags increased in household with children in general, portable shelter and cash being ignored.

Important: Maintaining *inventory does not mean they have inventory, just that they have neither increased nor reduced inventory! This is a one-to-one comparison between the 50 households identified as being included in both the 2010 and 2011.*



How to interpret: the green shaded areas shows the percentage increase of specific inventory by households, and the red shaded areas shows the percentage decrease by households. Take as an example face and dust masks: 30% of households without children increased their inventory of face and dust masks, and 9% reduced their inventory, the remaining 41% maintaining their inventory; whereas 7% of households with children reduced their inventory and the remaining 93% maintained their inventory.

Figure 5-8 : Household inventory - comparison of reduced, maintained, or increased inventory between 2010 and 2011 for those with and without children

5.2 Emergency supplies

An emergency supply is something that is easily accessible and usually kept on the person or nearby. A personal emergency supply pack consists of a water bottle, some nutritional food

such as an energy bar, a torch, and perhaps a radio, cell phone, and a whistle. A household emergency supply contains the provisions listed in the section above in a convenient box or rucksack that is accessible after an emergency. A household emergency supply may be portable, in which case it may also be called an emergency getaway kit.

5.2.1 Personal emergency kit

Participants were asked if they had a personal emergency kit with them at the time of the Christchurch and Sumner Earthquakes, respectively (Figure 5-9 and Figure 5-10). There was an increase in the number of participants having a personal emergency kit nearby during the earthquake. Those with children had a lower ownership level than those without.

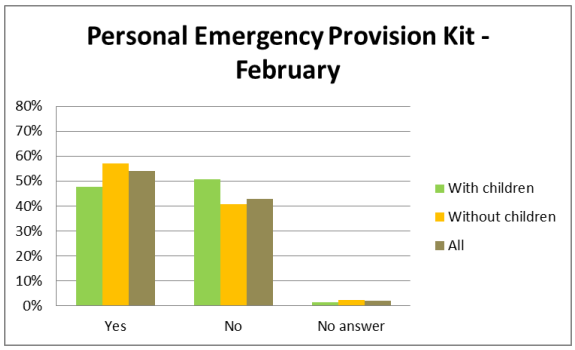


Figure 5-9 : Personal Emergency Kits - February 2011

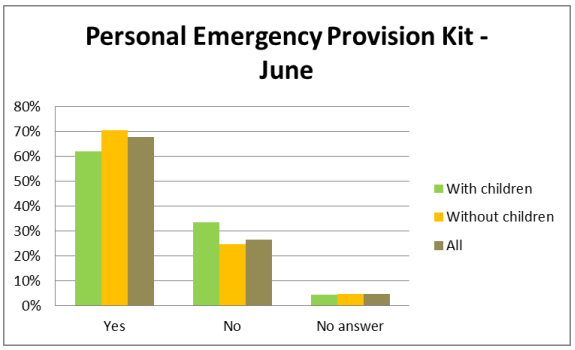


Figure 5-10 : Personal Emergency Kits - June 2011

The participants were asked if they had a personal emergency kit now, and where: at home; in the office; in the car.

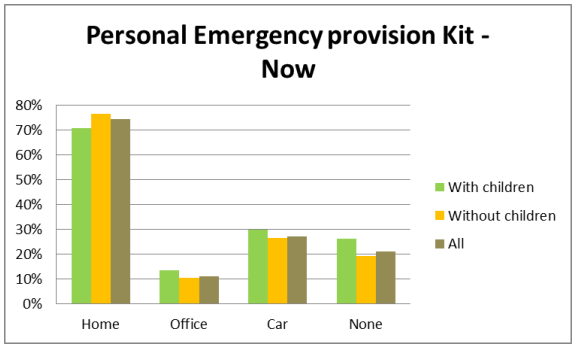


Figure 5-11 : Personal emergency provision kit ownership and location – now

25% of those participants with children and 20% of those without replied that they did not have a personal emergency kit. More than 70% replied that they had such a kit at home, with ca. 10% in the office, and 28% having one in the car.

5.2.2 Household emergency kit

Participants were asked if their household had an emergency kit (Figure 5-12 and Figure 5-13). 25% did not in February, falling to 15% in June. Of those that had one, 50% used it in February, falling to 42% in June.

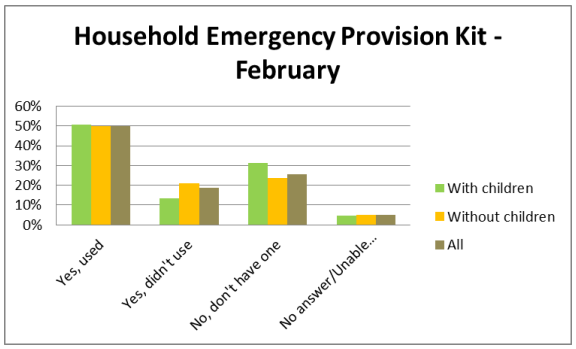


Figure 5-12 : Household Emergency Provision Kits – February 2011

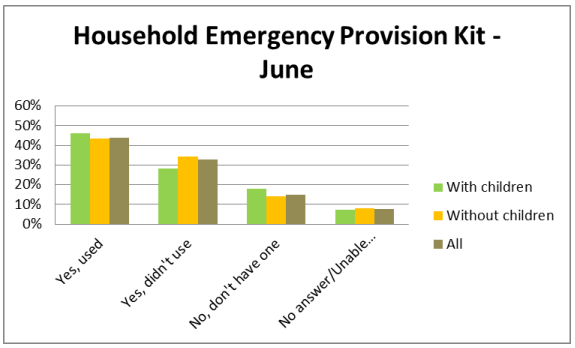


Figure 5-13 : Household Emergency Provision Kits – June 2011

The participants were further asked if their household emergency provision kits had lasted for 3 respective 7 days (Figure 5-14 - Figure 5-17).

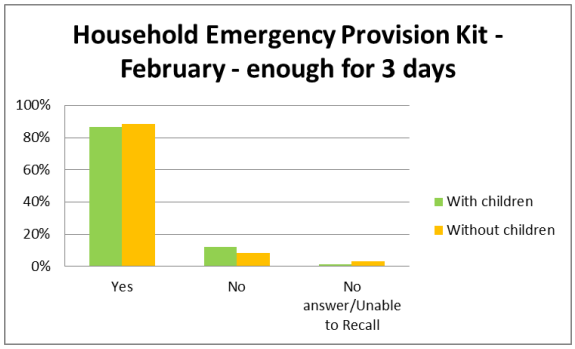


Figure 5-14 : Household Emergency Provision Kits – February - Enough for 3 days

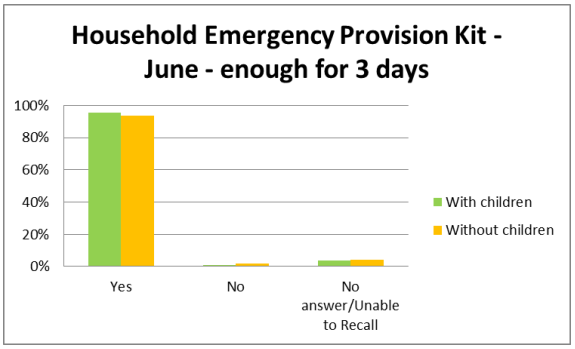


Figure 5-15 : Household Emergency Provision Kits – June - Enough for 3 days

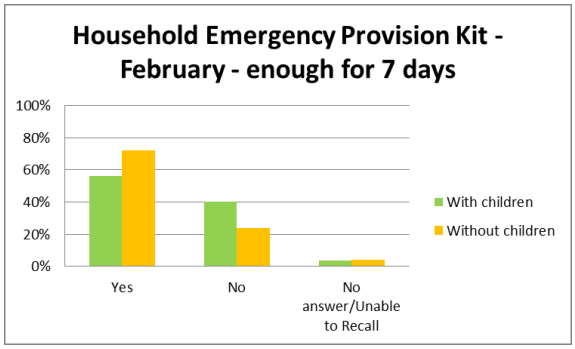


Figure 5-16 : Household Emergency Provision Kits – February - Enough for 7 days

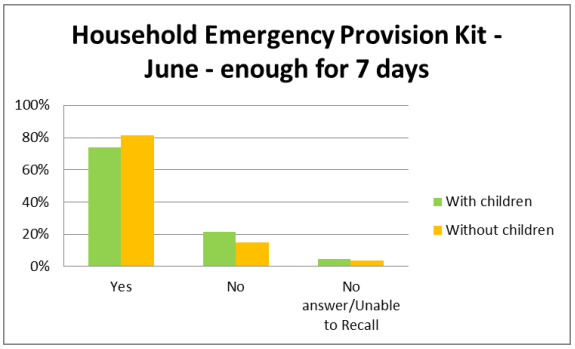


Figure 5-17 : Household Emergency Provision Kits – June - Enough for 7 days

The responses showed that in June emergency provisions provided more than 95% of the household requirements, whereas only 85% were covered in February. Households with children were consistently under-provisioned.

5.2.3 Re-provisioning

Participants were asked from where they obtained provisions during the 7 days after the Christchurch and Sumner Earthquakes. Most could get them from a dairy or city supermarket.

In February, the Royal New Zealand Navy's Multirole Vessel HMNZS CANTERBURY was berthed at Lyttelton as part of Exercise Southern Katipo (NZ Defence Force 2011). The ship's company organised a kitchen and cooked meals for many residents. On Sunday, 27th February, the ship left for Wellington to remove military supplies and equipment for that exercise and returned on Monday, 28th February with the available space filled with water, 20 plus vehicles, a fuel tanker, fire appliances, telecom vans, engineer bridging and general

materials. During her absence, HMNZS OTAGO and HMNZS PUKAKI continued to provide assistance to the people of Lyttelton, joined later by HMNZS PEGASUS.

The local supermarket cleared its shelves of stock that could spoil due to the failure of the electricity supply and allowed residents to take what they needed [pers comm].

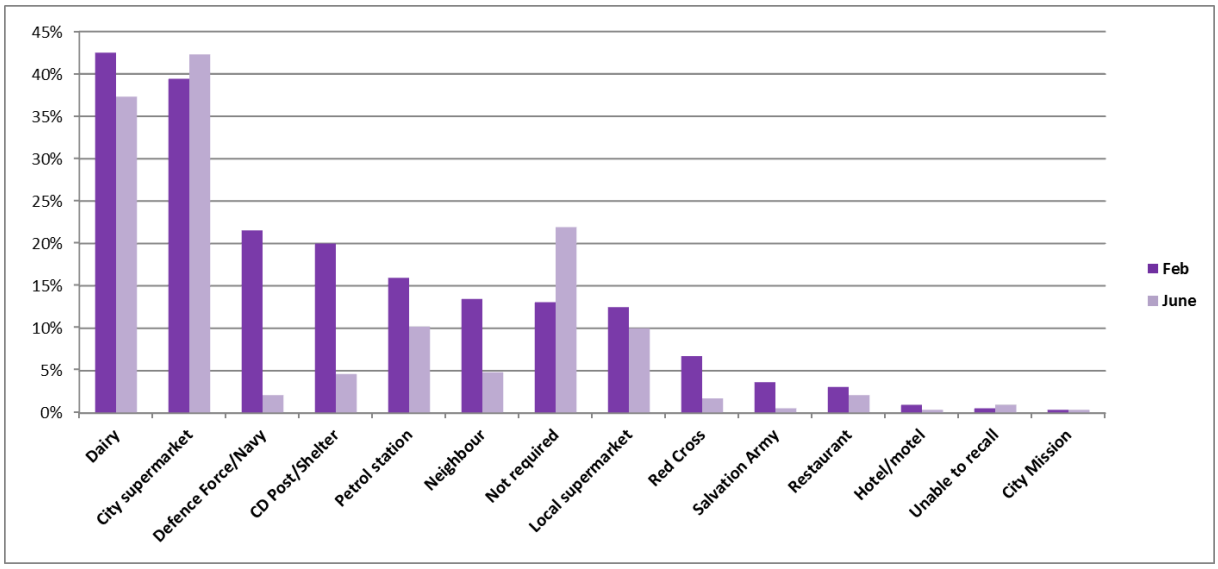


Figure 5-18 : Household re-provisioning in the 7 days after the Christchurch and Sumner Earthquakes

5.3 Discussion

This study shows that the majority of the study area population was not directly affected by the Darfield Earthquake (other than a short suspension of utilities) and so did not undertake preparations for another earthquake. As the Lyttelton Road Tunnel and Evan's Pass were shut for a time, residents were required to drive over Dyers Pass Road to visit a supermarket. Even after the Christchurch Earthquakes, when the population was very much affected, they did not undertake to increase their preparedness for a further disaster. There are parallels here with the Loma Prieta, California, Earthquake of October 17, 1989. The lack of main-shock damage of the Loma Prieta Earthquake created a "normalisation bias" for non-victims. This bias limited their perception of risk to damaging aftershocks and protective response to warnings (Mileti & O'Brien 1989).

It is likely that, after Darfield Earthquake, some people in the study population would have thought the threat of a devastating earthquake had passed, and therefore they would not need to be prepared for another. The Christchurch Earthquake would have shocked them,

but again, would they have needed to become more prepared for another, large earthquake/aftershock, as warned by GNS Science?

> *"We're most unlikely to have a future serious earthquake in our lifetimes. Present tensions will fade" – reply from 2011 Survey*

> *"What astounds me is my own failure to prepare for future disasters having survived three earthquakes. We still don't have a readily accessible and comprehensive survival kit. I'm not sure why that is. Is it just the sheer exhaustion that follows such events that makes one disinclined to prepare for another? Is it the hope there won't be another? Whatever the reason it means despite all the information that's been disseminated to us and our own experiences, we are still unprepared for a disaster!" – reply from 2011 Survey*

About the same number of households used their household emergency kit in February 2011 as did in June 2011. About twice as many had one but did not use it. The percentage of households that did not have a household emergency kit fell from ca. 20% in February 2011 to 10% in June 2011. This last finding contradicts some comments received:

> *"Every time we have another earthquake, we swear we will get our survival kits together." – reply from 2011 Survey*

Of important note is that > 80% of the population has supplies to last for 3 days. For seven days' supply, this dropped to about 50% for the population in February 2011, but rose to 75% by June 2011. This may have been because in June people were more prepared and had stocked up, but it may also be because the town was not cut off from Christchurch for as long as it was in February.

It is likely that having the Navy in port at the time of the Christchurch Earthquake in February calmed fears. The order and discipline of the sailors would probably have steadied the population that came into contact with them. Their action in setting up a food station was a focal point for the community in Lyttelton.

> *"We very much appreciated the help of the navy during the Feb quake, Life would have been very dire if they hadn't been around. It was amazing to see how Lyttelton pulled together." – reply from 2011 Survey*

"The Army and Red Cross' immediate response has been invaluable" – reply from 2011 Survey

It is unsure how much this outside help benefitted residents in Cass Bay and Rapaki, as no mention was made of the Navy from their replies. Together with the Navy, the local emergency services stepped in where leadership from Civil Defence was not apparent.

In June, due to broken chimneys, many residents were not able to heat their homes other than to use electric oil heaters. Given how expensive they are to run, people with little means are vulnerable to the cold as they cannot afford to keep warm. One participant in the 2011 survey quoted receiving an electricity bill of over NZD 600 in order to keep warm over some of the coldest weather in a century.

In the 2011 survey, two new provisions were added: a tent or other portable shelter; and, cash. It is interesting to note that the highest percentage of households with cash on hand came from the group with the highest Deprivation Index. This could be because they operate in a cash economy and rely less on banks and credit cards.

6 Post-event movement of the population

This chapter analyses the spatiotemporal movement of the normally resident population of Lyttelton and surrounding area. The 2011 survey was used to compare the whereabouts of the individuals of households when the Christchurch and Sumner Earthquakes occurred, where they moved to, how long it took, the mode(s) of transport they took, and if and where they evacuated to. This analysis informs the objective of the research concerned with the immediate response of the population.

6.1 Contacting other household members, friends and family

Due to the disorientation the earthquakes had on people, many of them first tried to contact friends and family. To many this may have offered relief but for others it may have been a source of consternation as phone lines were blocked, telephones went unanswered, calls were dropped, or messages were not answered.

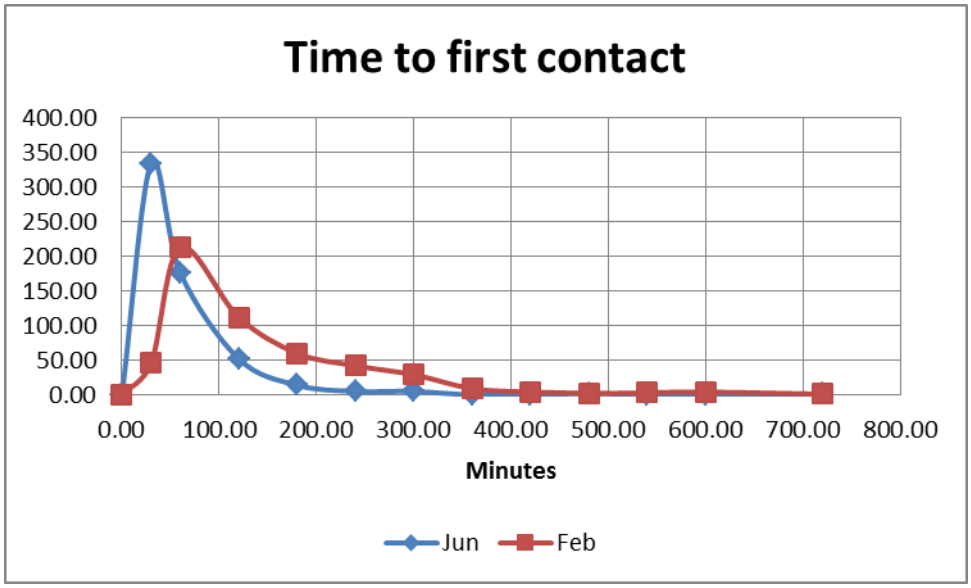


Figure 6-1 : Time it took to contact a family member – February 2011 vs. June 2011

The participants recorded 479 contacts with family members in the first 6 hours after the Christchurch Earthquake, and 255 contacts in the first 6 hours after the Sumner Earthquakes. Figure 6-1 shows the distribution of the time it took to contact family. In February, 174 contacts were made immediately (mostly due to physical proximity), increasing to 241 in June.

6.1.1 Landline telephones

Many households now use wireless phones, consisting of a mains-powered base station that takes a call (and sometimes includes an answering machine) and relays it to one or more handsets using short-distance radio waves. Due to the power outages, even though the telephone network was still functioning on back-up battery power, many households were unable to make or receives telephone calls as their base station units were not working.

Shortly after the quake, Telecom began collecting "old-fashioned" analogue phones that plug in directly to the telephone socket from donors around the country for redistribution in Christchurch (Telecom New Zealand 2011).

6.1.2 Cellular telephone

The use of text messaging (TXTing) or SMS has become ubiquitous and commonplace for recreational and business purposes. It was used to good effect immediately following the Christchurch and Sumner Earthquakes when friends and family wanted reassurance others were OK, or in planning to meet somewhere. Indeed, people were urged through messages over the public radio broadcasts to TXT rather than voice-call someone.

> *"Cellphones - allowed us to know that our family i.e. children were ok immediately after both quakes. We could txt teachers and get a reply to know they were ok. This is a very powerful tool - to be able to know young ones are safe" – reply from 2011 survey*

Unfortunately, some TXTs did not get through or were delayed, raising the angst of the sender that the recipient was in trouble. This is similar to what you can experience around events such as New Year, when many people send (but still get billed for) TXTs but many do not arrive.

Although Emergency Alert Systems (EAS) over SMS is still in its infancy in New Zealand (NRC 2012) and has only just been implemented for Christchurch and Canterbury (ECan 2011a), (Traynor 2008) argues and demonstrates several reasons why EAS over SMS in current cellular systems is simply not feasible or recommended, such as:

- Cellular networks are not designed to delivery emergency-scale traffic loads
- Cellular networks are not the Internet

- Targeting users in a specific location is extremely difficult
- There is no way to authenticate the source of messages, making fraudulent alerts easy to send
- SMS is not a real-time service
- Message delivery order is not always predictable

The physical infrastructure was able to cope, mainly due to lessons learned from the 1996 Canterbury snow storm when cell towers worked on batteries until depleted and then failed (Wilson et al. 2009). Telecom reported having 60 portable generators deployed to network sites without power a few days after the Christchurch Earthquake (ONE News 2011).

6.2 Immediate homeward journey after the Christchurch and Sumner Earthquakes

It was shown by the results of the survey that side-trip and trip-chaining behaviour was evident after the Christchurch and Sumner Earthquake events when individuals were returning to their homes or meeting places after a disaster. Many of these detours can be explained as attempting to ascertain the location and status of other household or family members, or of property other than the family home. Some people helped others to get home by providing them with transport, even if it meant driving a detour.

This extra traffic on an overstretched and damaged road network exacerbated the congestion. At road junctions, lack of electricity meant automatic traffic light signals were not operational.

6.2.1 Travel times

The respondents were asked in the 2011 Survey how long it took them to travel home. They reported on 702 journeys after the Christchurch Earthquake and 583 journeys after the Sumner Earthquakes.

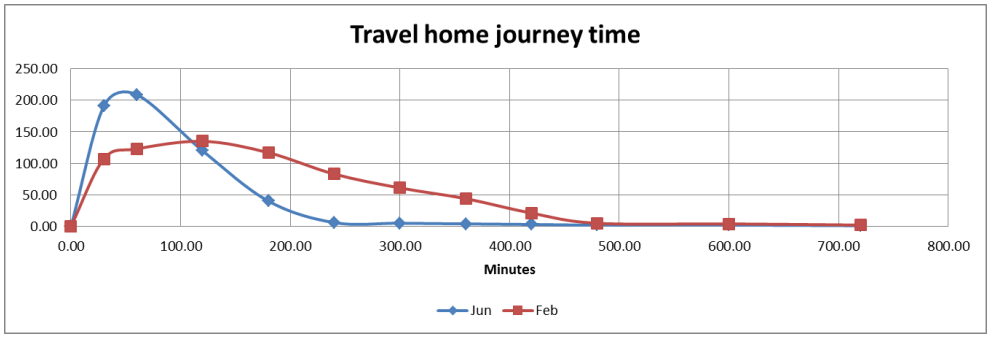


Figure 6-2 : Travel home journey time - February 2011 vs. June 2011

The journey time in June was much quicker than that for February, even though the Evan's Pass Road was not in operation (Figure 6-2). Perhaps it was because this was known about, time was not heedlessly spent attempting to drive via Sumner to get home using that route after the June events. The average journey time home for those completing it within the first 6 hours was 161 minutes in February and 81 minutes in June.

14 individuals reported spending 24 hours or more in returning home in February, but this involved stopping at a friend or family member's home for the night, or returning from abroad.

In February, 88 individuals reported being home (a zero-minute journey) and in June that had risen to 106.

6.3 Origins

6.3.1 Pre-September 2010

In the pre-September 2010 survey, the respondents were asked their place of school or work so that a destination/origination map could be generated.

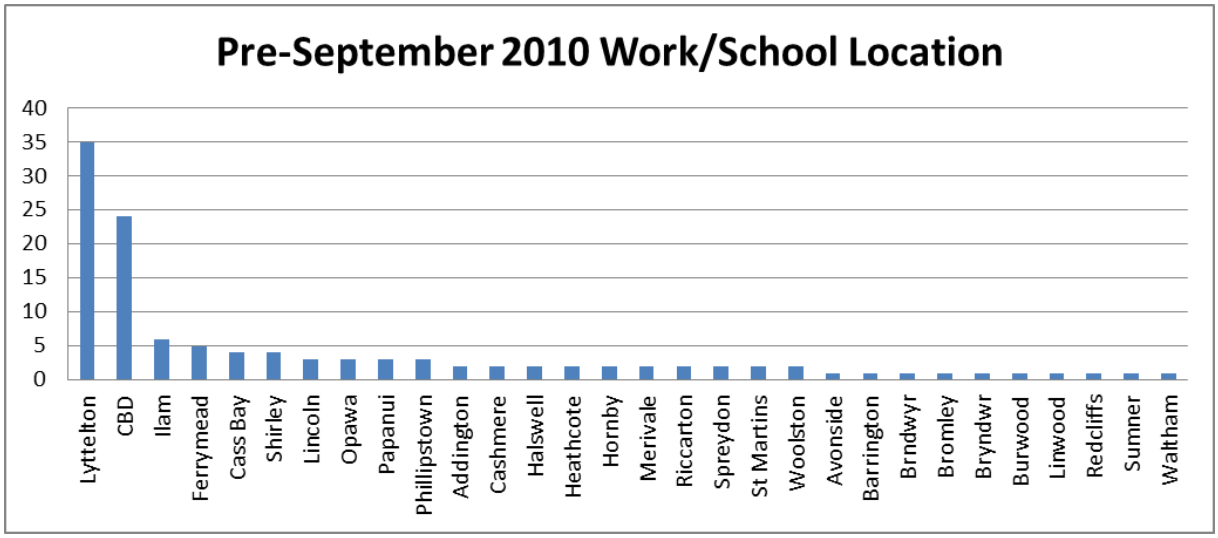


Figure 6-3 : Pre-September 2010 Work/School Location

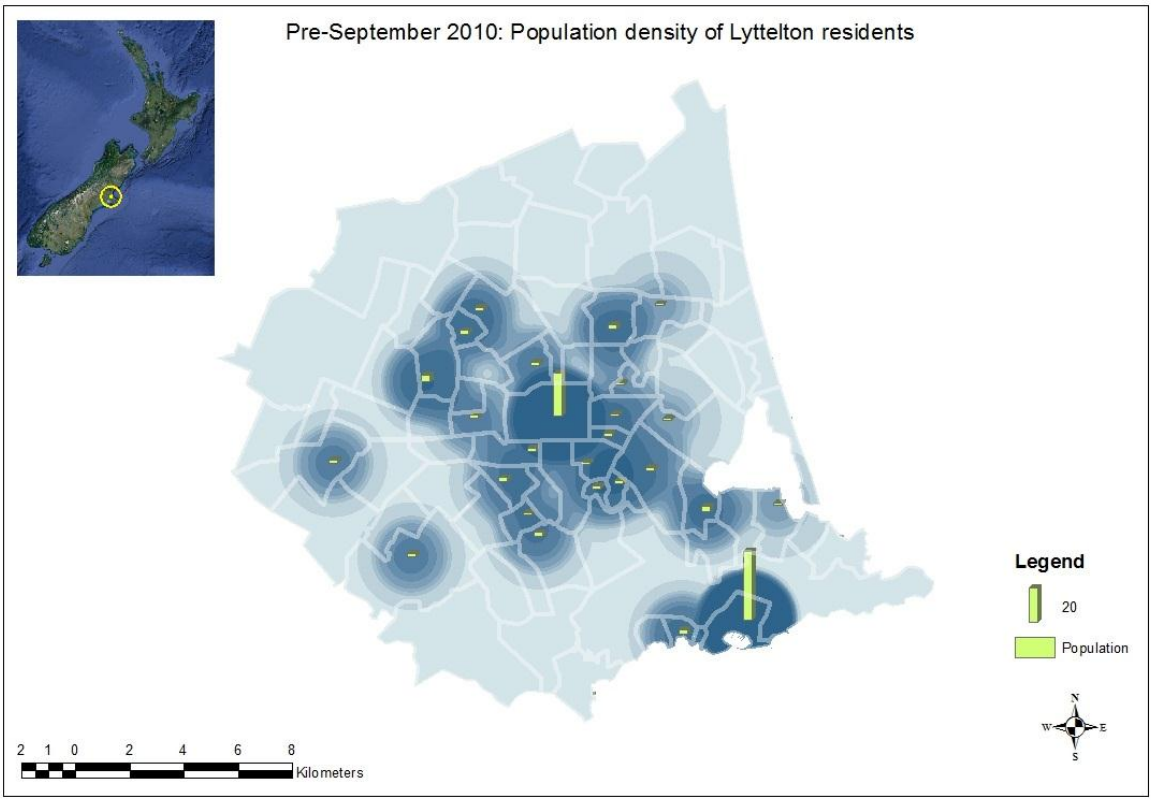


Figure 6-4 : Pre-September 2010 population density of Lyttelton residents in Christchurch suburbs

84% of respondents reported they would use the Lyttelton road tunnel as their preferred route of ingress/egress, with 4% indicating Evan's Pass, and 3% via Rapaki on Governor's Bay Road. 9% gave no response.

73% of respondents that gave an answer reported they use a private car as their primary mode of transport, with 10% sharing a car with another person (not necessarily from their own household). 11% answered that they use the public bus, and 4% and 2% travelled on foot or by bicycle, respectively. No-one reported using a taxi as their primary mode of transport.

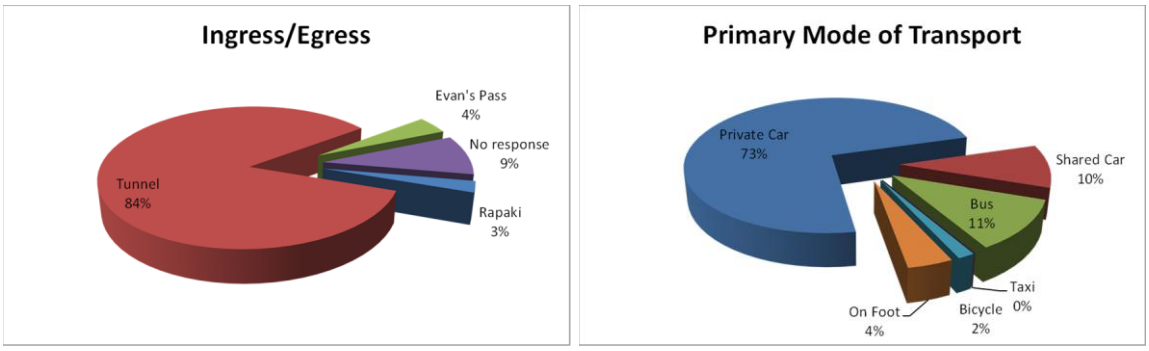


Figure 6-5 : Preferred ingress/egress routes and primary mode of transport

6.3.2 February 2011

Respondents reported their whereabouts during the initial 22nd February and 13th June (13:00) earthquakes.

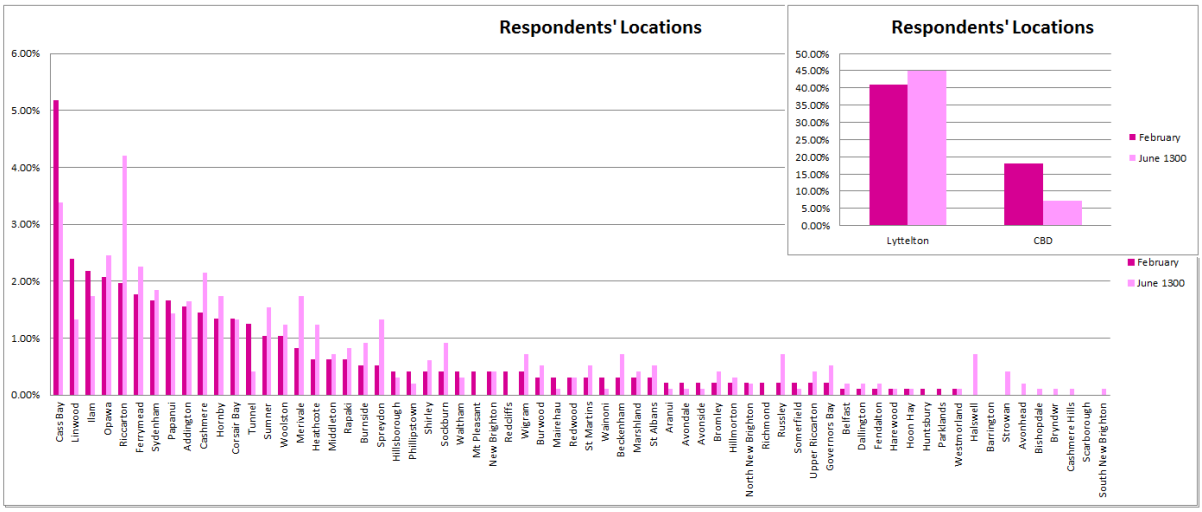


Figure 6-6 : Respondents' Locations during the initial Christchurch and Sumner Earthquakes

There was a marked decrease in the number of people reporting their locations in February as being in the CBD and Halswell: this is mainly due to the Darfield Earthquake, the effects

of which reduced access and closed many businesses. The increase in respondents in outer suburbs may be attributed to relocation of businesses from the CBD.

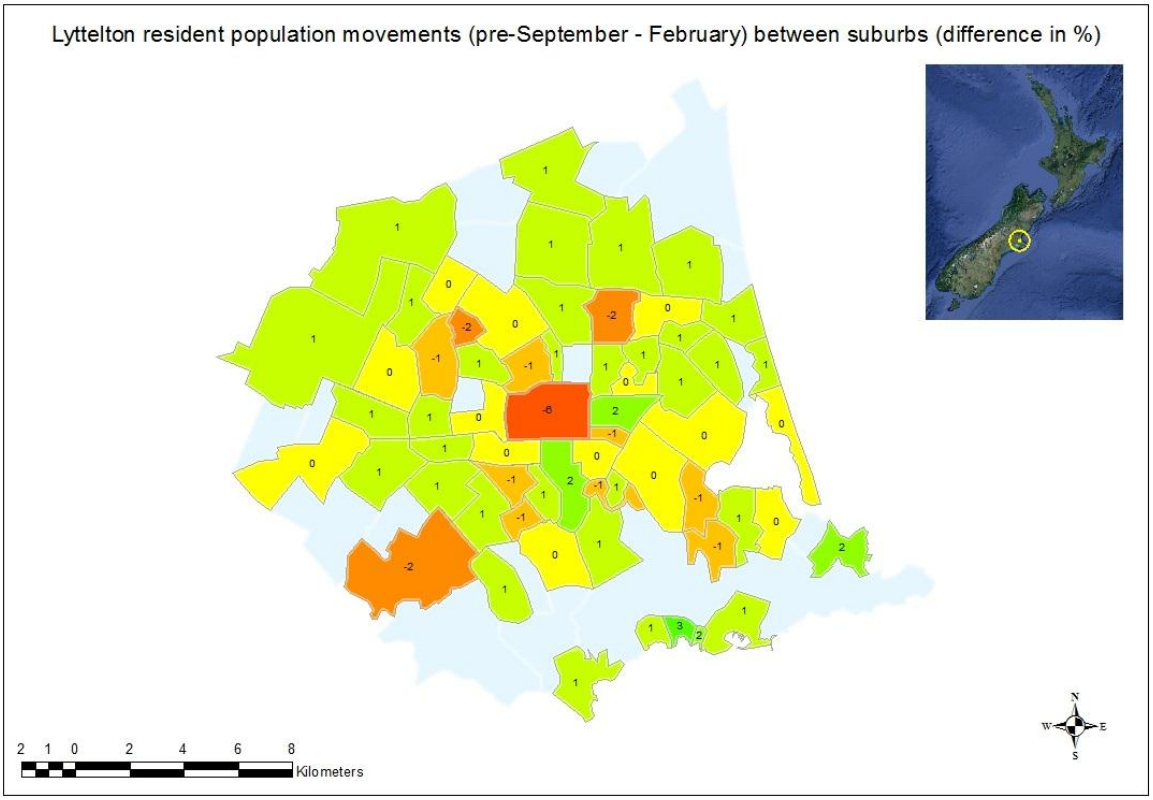


Figure 6-7 : Changes in population density of Lyttelton residents between pre-September 2010 and February 2011

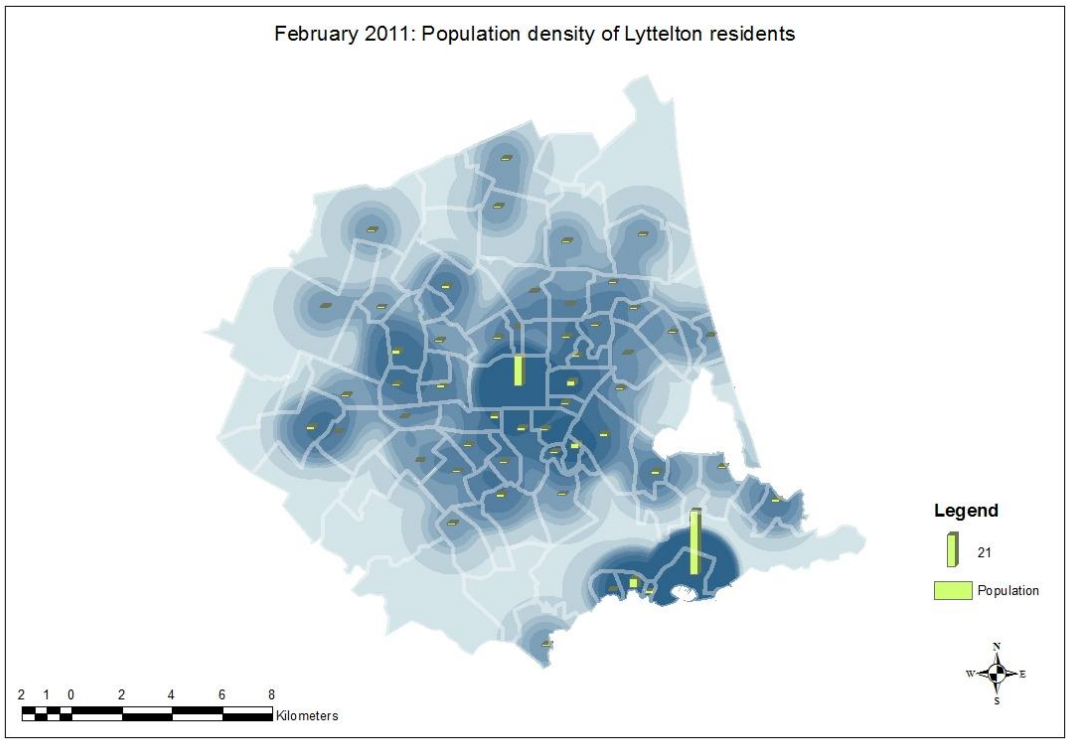


Figure 6-8 : February 2011 - population density of Lyttelton residents in Christchurch suburbs

Respondents were asked all modes of transport they used to get home. The alternatives were:

- Drove own vehicle
- Rode in a vehicle belonging to another household member, a neighbour, or a friend
- Rode in a vehicle with a stranger
- Took a taxi
- Rode the bus
- Rode own bicycle
- Went on foot

In February 2011, of the 878 combined journeys recorded, the majority (55.5%) were made (at least in part) using their own vehicle. A further 24.0% (not including those that drove themselves a part of the way) rode in a vehicle driven by another household member, a friend or a neighbour. 15.9% made the journey home solely on foot.

Table 6-1 : Modes of transport taken - February

D	R	S	T	B	C	F	Qnt	%
✓	✓					✓	7	0.8%
✓	✓						12	1.4%
✓		✓		✓			1	0.1%
✓		✓				✓	5	0.6%
✓		✓					3	0.3%
✓				✓		✓	1	0.1%
✓					✓	✓	3	0.3%
✓					✓		1	0.1%
✓						✓	62	7.1%
✓							392	44.6%
	✓	✓				✓	6	0.7%
	✓	✓					1	0.1%
	✓			✓		✓	2	0.2%
	✓			✓			3	0.3%
	✓				✓		2	0.2%
	✓					✓	31	3.5%
	✓						166	18.9%
		✓	✓				1	0.1%
		✓				✓	8	0.9%
		✓					11	1.3%
			✓				1	0.1%
				✓		✓	4	0.5%
				✓			7	0.8%
					✓	✓	3	0.3%
					✓		5	0.6%
						✓	140	15.9%
							878	100.0%

Code	Description of mode of transport
D	Drove own vehicle
R	Rode in a vehicle belonging to another household member, a neighbour, or a friend
S	Rode in a vehicle with a stranger
T	Took a taxi
B	Rode the bus
C	Rode own bicycle
F	Went on foot

6.3.3 June 2011, 13:00

The respondents were asked to report their location for the 13th June, 13:00 Sumner Earthquake.

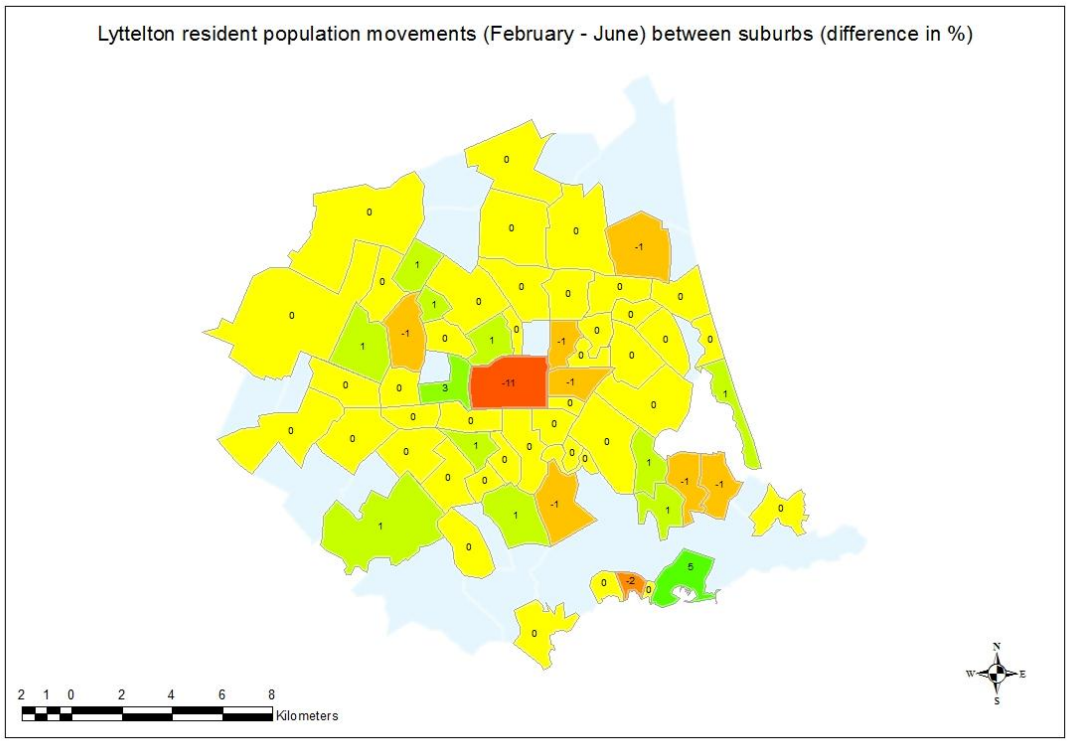


Figure 6-9 : Changes in population density of Lyttelton residents between 22nd February 2011 and 13:00 13th June 2011

The data showed a marked decrease in the number of people reporting their locations in June as being in the CBD (Figure 6-6): this is probably due to the Christchurch Earthquake, the effects of which reduced access due to the cordon (CERA 2012) and forced many businesses to close and relocate.

The decrease was accompanied by a slight increase in the number of people located in Lyttelton. Again, the increase in respondents in Riccarton, Halswell, Barrington, and Merivale may be attributed to the closure of retail businesses in the CBD.

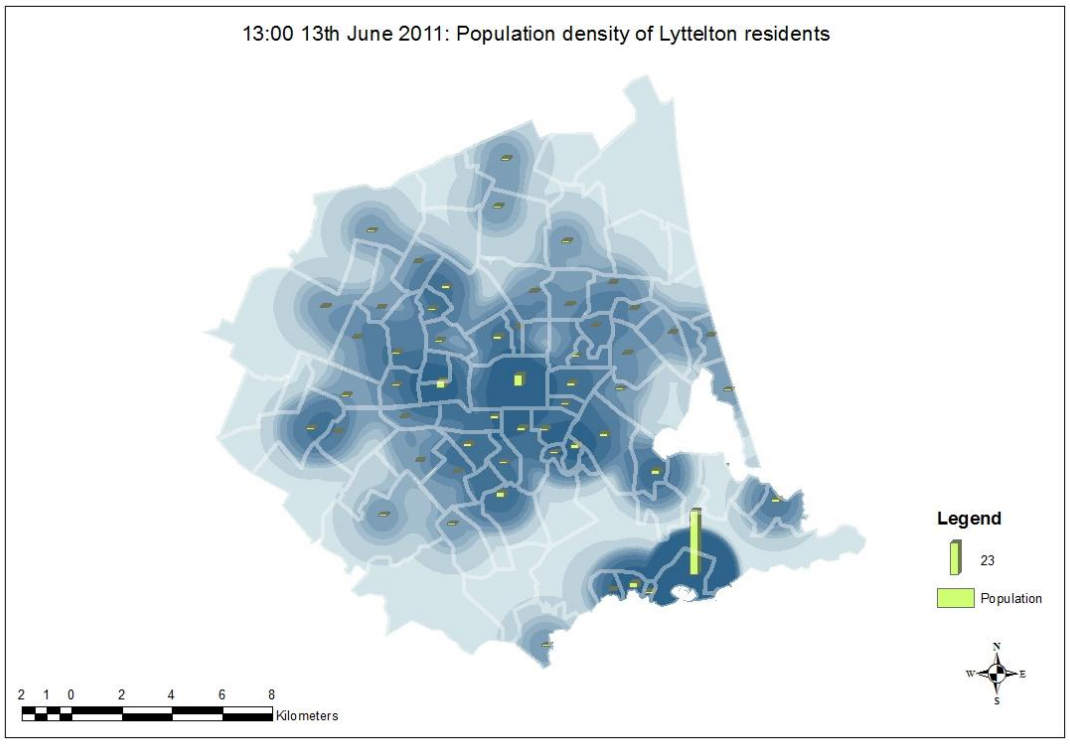


Figure 6-10 : 13:00 13th June 2011: population density of Lyttelton residents in Christchurch suburbs

6.3.4 June 2011, 14:20

The respondents were asked to report their location for the 13th June, 14:20 Sumner Earthquake. This information has been used to show how the aggregate of people moved in the 80 minutes between the two events.

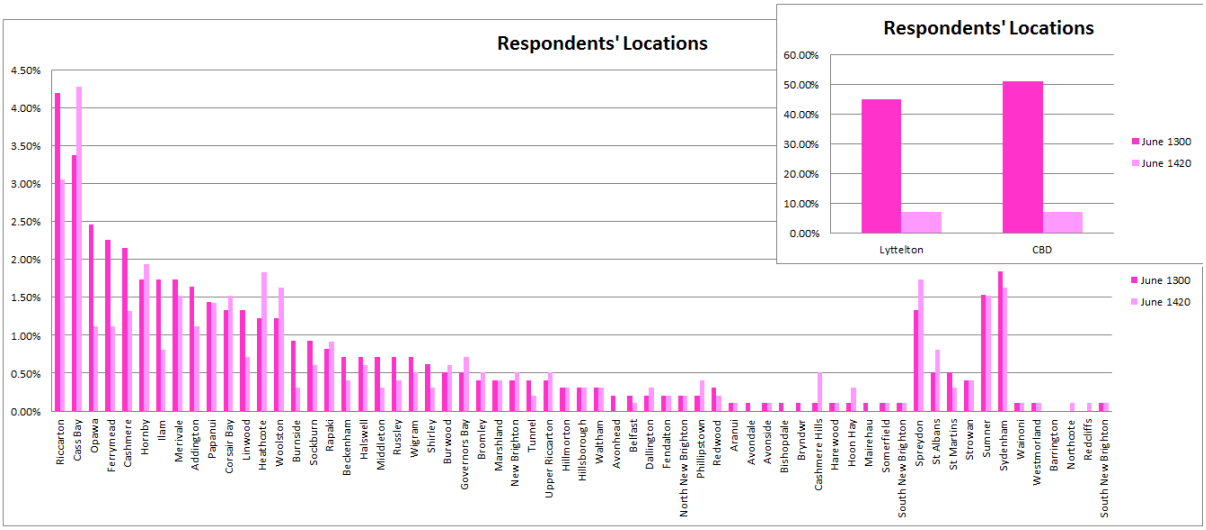


Figure 6-11 : Respondents' Locations during the 13:00 and 14:20 Sumner Earthquakes on 13th June

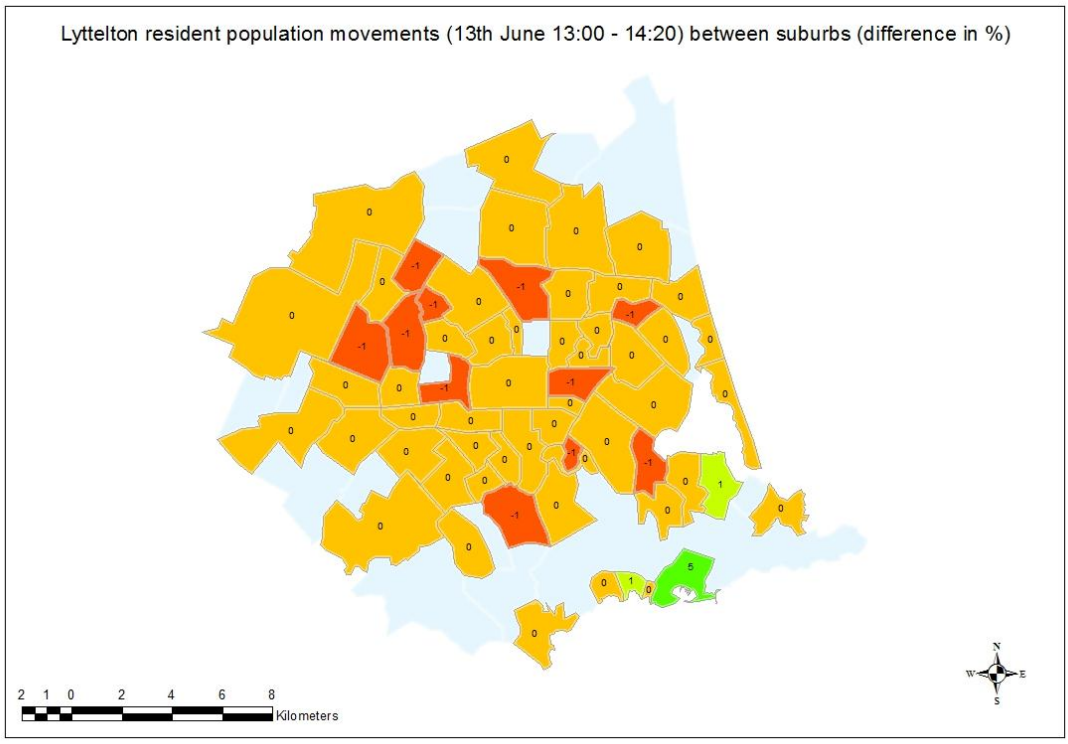


Figure 6-12 : Changes in population density of Lyttelton residents between 13:00 and 14:20 13th June 2011

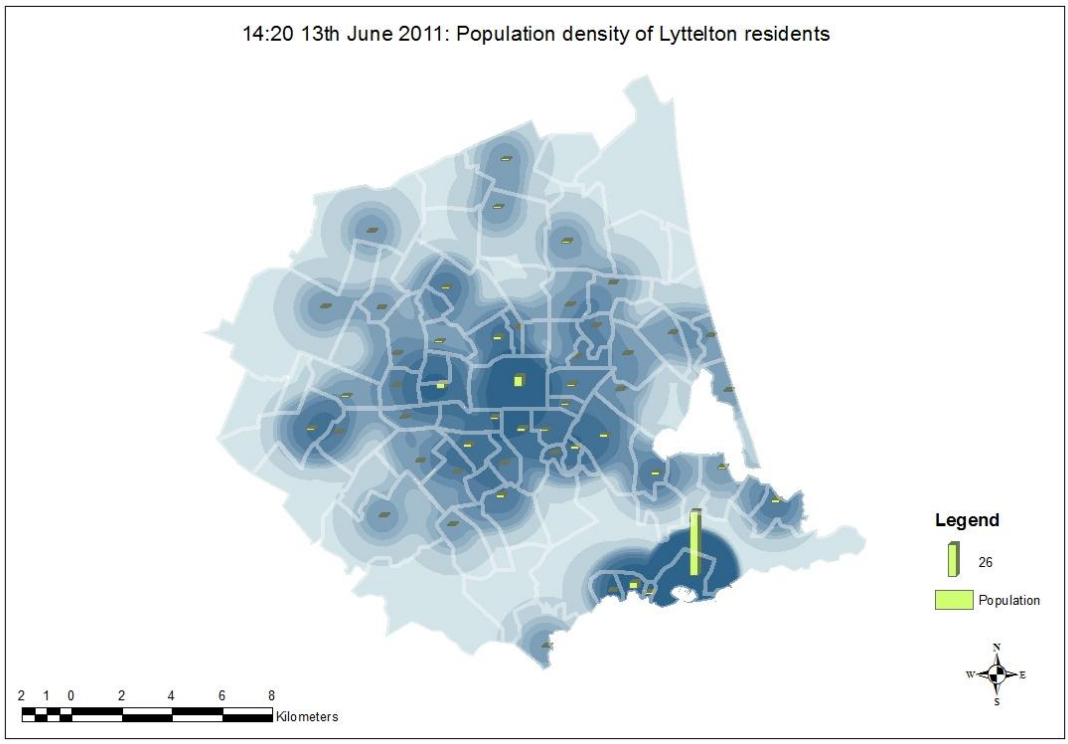


Figure 6-13 : 14:20 13th June 2011: population density of Lyttelton residents in Christchurch suburbs

The location reports show a redistribution of the respondents towards the study area, although some people at home in Lyttelton travelled out in order to help other household members.

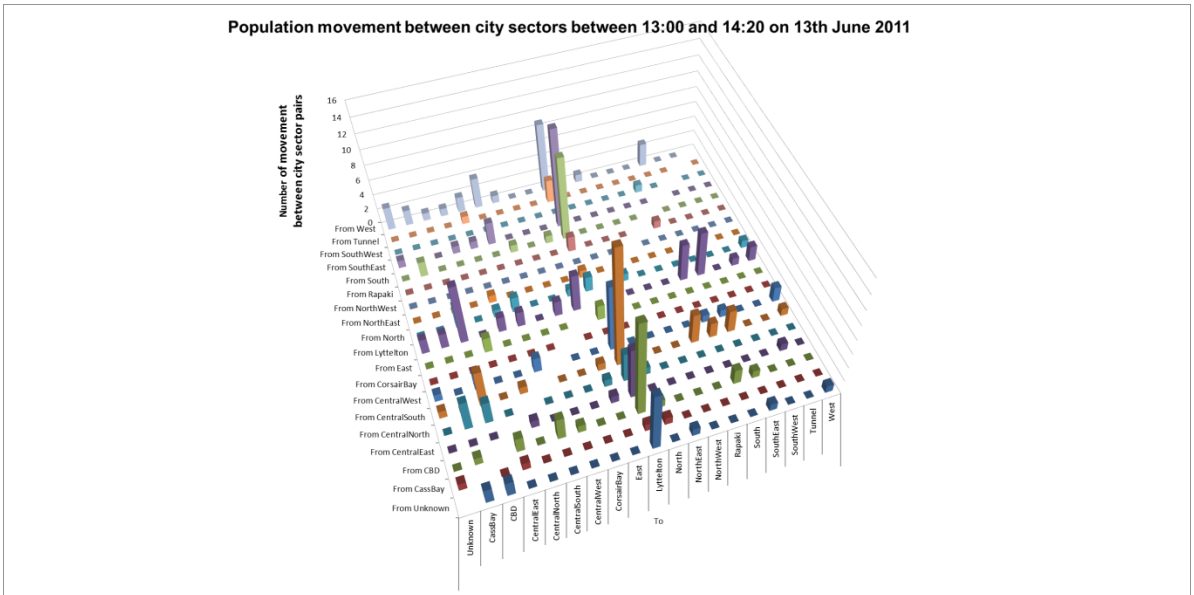
A movement analysis was performed for the 13th June event, using people's reported localities at the 13:00 and 14:20 events. Localities were first aggregated into city sectors to reduce complexity:

Table 6-2 : City sectors and localities

Sector	Localities				
Cass Bay	Cass Bay				
CBD	CBD				
Central East	Avonside	Dallington	Linwood	Phillipstown	Richmond
Central North	Bryndwr	Merivale	Strowan	St Albans	Edgeware
Central South	Addington	Opawa	Somerfield	Spreydon	St Martins
	Sydenham	Waltham	Barrington	Hoon Hay	
Central West	Fendalton	Hillmorton	Middleton	Riccarton	Riccarton Park
Corsair Bay	Corsair Bay				
East	Aranui	Avondale	Bromley	New Brighton	South New Brighton
	Wainoni	Woolston	Bexley		
Lyttelton	Lyttelton	Ship in Harbour			
North	Belfast	Bishopdale	Casebrook	Mairehau	Marshland
	Northwood	Papanui	Redwood	Shirley	
North East	Waimari Beach	Burwood	North New Brighton	Parklands	Spencerville
North West	Harewood				
Rapaki	Rapaki				
South	Beckenham	Cashmere	Cashmere Hills	Cracroft	Governors Bay
	Hillsborough	Port Hills	Huntsbury	Westmorland	
South East	Ferrymead	Heathcote	Mt Pleasant	Redcliffs	Sumner
	Monck's Bay				
South West	Halswell	Oaklands	Paparoa	Kennedy's Bush	
Tunnel	Tunnel				
West	Avonhead	Burnside	Hornby	Ilam	Russley
	Islington	Sockburn	Upper Riccarton	Wigram	Hei Hei

Figure 6-14 shows the number of journeys made by the resident population of Lyttelton within the city sectors. No journey has been recorded where someone has not travelled across a sector boundary. Of particular interest are the journeys originating in Lyttelton. It

shows people travelled from Lyttelton into the South (5), South East (6), and East sectors (5), as well as into the CBD (8).



	To																		
	Unknown	CassBay	CBD	CentralEast	CentralNorth	CentralSouth	CentralWest	CorsairBay	East	Lyttelton	North	NorthEast	NorthWest	Rapaki	South	SouthEast	SouthWest	Tunnel	West
From Unknown		2	2	0	0	0	0	0	0	8	0	1	0	0	0	1	0	0	1
From CassBay	1		0	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
From CBD	0	1		2	0	3	1	0	0	13	1	0	0	0	2	1	0	0	0
From CentralEast	0	0	0		1	0	0	0	1	7	0	0	0	0	0	0	0	1	0
From CentralNorth	0	4	3	0		0	0	0	1	4	1	0	0	0	0	0	0	0	0
From CentralSouth	1	0	5	0	1		0	0	1	16	0	0	0	4	2	3	0	0	1
From CentralWest	1	0	2	0	0	2		0	0	9	0	0	0	0	1	1	0	0	2
From CorsairBay	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0
From East	0	0	0	2	0	0	0	0		2	0	0	0	0	0	0	0	0	0
From Lyttelton	2	2	8	0	2	2	0	2	5		2	0	0	0	5	6	0	1	2
From North	0	0	3	0	1	2	0	0	1	2		1	0	0	0	0	0	0	1
From NorthEast	0	0	0	0	1	0	0	0	0	1	0		0	0	0	0	0	0	0
From NorthWest	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0
From Rapaki	0	0	0	0	0	0	0	0	0	2	0	0	0		1	0	0	0	0
From South	0	2	0	0	0	0	1	0	1	11	0	0	0	0		0	0	0	0
From SouthEast	1	0	0	1	1	3	0	0	0	13	0	0	0	0	0		0	0	0
From SouthWest	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0		0	0
From Tunnel	0	0	0	0	1	0	0	0	0	3	0	0	0	0	0	0	0		0
From West	3	2	1	1	2	4	1	0	0	9	2	1	0	0	0	3	0	0	

Figure 6-14 : Resident Lyttelton population movement between city sectors between 13:00 and 14:20 on 13th June 2011 – Population

In June 2011, of the 783 combined journeys recorded, the majority (67.3%) were made (at least in part) using their own vehicle. A further 20.4% (not including those that already drove themselves a part of the way) rode in a vehicle driven by another household member, a friend or a neighbour. 9.8% made the journey home solely on foot.

Table 6-3 : Modes of transport taken - June

D	R	S	T	B	C	F	Qnt	%
✓	✓					✓	1	0.1%
✓	✓						6	0.8%
✓		✓					1	0.1%
✓						✓	3	0.4%
✓							516	65.9%
	✓	✓			✓	✓	1	0.1%
	✓	✓					1	0.1%
	✓			✓			2	0.3%
	✓					✓	1	0.1%
	✓						155	19.8%
		✓				✓	1	0.1%
		✓					4	0.5%
			✓				2	0.3%
				✓	✓		1	0.1%
				✓		✓	1	0.1%
				✓			3	0.4%
					✓		7	0.9%
						✓	77	9.8%
							783	100.0%

Code	Description of mode of transport
D	Drove own vehicle
R	Rode in a vehicle belonging to another household member, a neighbour, or a friend
S	Rode in a vehicle with a stranger
T	Took a taxi
B	Rode the bus
C	Rode own bicycle
F	Went on foot

6.3.5 Out of town respondents

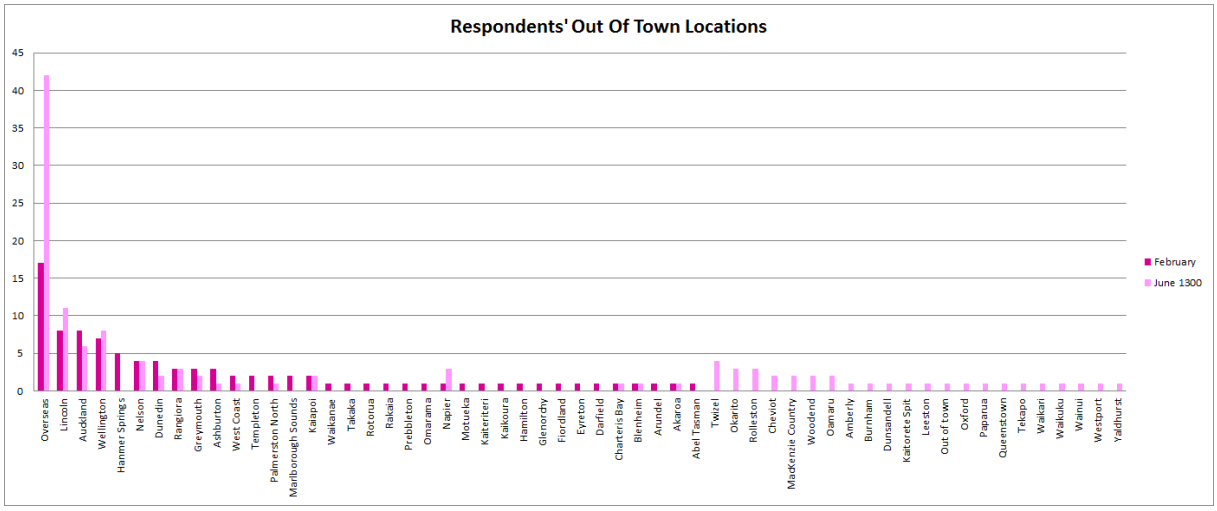


Figure 6-15 : Respondents' Locations during the initial Christchurch and Sumner Earthquakes for those out of town

Respondents in out of town locations were widespread and there was no appreciable increase between February and June. The majority of respondents out of town in June were overseas; based on replies, many of the respondents were on holiday.

6.4 Subsequent journeys

Some respondents who were at home in the study area at the time of the Christchurch and Sumner Earthquake(s) immediately struck out on a journey towards Christchurch. Replies report reasons such as contacting other household members, buying provisions, curiosity (reconnaissance), and wishing to help others in need (emergency services or volunteers).

After the Christchurch Earthquake, the respondents reported making 1380 separate journeys to 170 unique destinations. After the Sumner Earthquakes, the respondents reported making 918 separate journeys to 91 unique destinations.

The top journey destinations were given as:

Table 6-4 : Top journey destinations after the Christchurch and Sumner earthquakes

	Feb	Jun
Lyttelton	564	494
CBD	68	37
Heathcote	39	18
Cass Bay	34	47
Opawa	32	12
Sumner	29	12
Cashmere	25	18
Bridle Path	24	0
Halswell	17	13
Linwood	16	8
Sydenham	16	8
Rapaki	15	10
St Martins	15	4
Riccarton	14	16
Spreydon	14	10
Hillsborough	13	0
Ferrymead	12	7
Hagley Park	12	4
Ilam	12	3
Papanui	12	11
Rangiora	12	2
Mount Pleasant	11	0
Woolston	11	4
Bromley	10	5

The reasons reported for travelling included:

Table 6-5 : Some popular reasons given for subsequent journeys

Reason to travel	Count	Column % N=1242
Return home	476	38.3%
Go to work	98	7.9%
Collect children	94	7.6%
Go to meeting point	92	7.4%
Shelter at neighbours	82	6.6%
Care for other family	81	6.5%
Shelter with other family	76	6.1%
Collect household member	62	5.0%
Check house	33	2.7%
Local shelter	27	2.2%
Care for neighbours	22	1.8%
Evacuate household	22	1.8%
Care for household	12	1.0%
Volunteer	12	1.0%
Take someone home	11	0.9%
Evacuate self	9	0.7%
Seek medical attention	8	0.6%
Holiday	6	0.5%
Seek provisions	5	0.4%
Looking for animals	4	0.3%
Evacuate other family	3	0.2%
Looking around	3	0.2%
Evacuate others	2	0.2%
Retrieve car	2	0.2%
	1242	100.0%

6.5 Ingress-egress routes

There are three main vehicular routes into Lyttelton: the Lyttelton road tunnel (to Heathcote); Evan's Pass (to Sumner); and, Governor's Bay Road (via Rapaki) towards Governor's Bay, Dyer's Pass, and Gebbies Pass. All routes are subject to rock fall danger in the case of a strong earthquake.

The port can facilitate larger vessels so evacuation could occur, should the port facilities be operational. Rapaki and Cass Bay each have jetties that can accommodate smaller vessels, if required.

6.5.1 Pedestrian/cycle tracks

The Bridle Path, Major Hornbrook Track, and Chalmers Track are popular walking tracks leading to Mt Cavendish, above Lyttelton. The Bridle Path is capable of taking a vehicle.

A number of Lyttelton residents reported in their replies that they used the Bridle Path to navigate over the Port Hills on their return home. Owen Wright, 40, a Lyttelton resident, was subsequently killed during an aftershock by falling rocks on the Major Hornbrook Track, shortly before reaching his home and family (Mann 2011).

Figure 6-16 : Rock fall on slope and walking track below Gondola Building (possible fatality site) (GNS Photo-GTH_5933) (Hancox et al. 2011)

The ferry service to Diamond Harbour offers a further route for cyclists and pedestrians. Service was affected by the damage to the dock at Lyttelton but resumed in early March 2011 (Bingham 2011).

6.5.2 Governor's Bay Road

Governor's Bay Road is subject to rock fall danger (the boulder that passed through the house at 241 Governor's Bay Road is evidence of the danger) and slumping. Dyer's Pass road remained open after the earthquakes but care and a certain amount of courage was

required to navigate around the dislodged boulders on the road. Gebbies Pass remained opened with little road damage.

6.5.3 Evans Pass Road/Sumner Road Closures

After the Darfield and Christchurch Earthquakes, Evan's Pass remained closed whilst scaling and blasting work was undertaken on the exposed cliffs and bluffs above and below the road. After briefly re-opening before the Christchurch Earthquake and subsequently re-closed, it has since not been opened.

Figure 6-17 : Evan's Pass Road (Julian Idle 2012)

Figure 6-18 : Evan's Pass Road carriageway collapse (Alexander 2010)

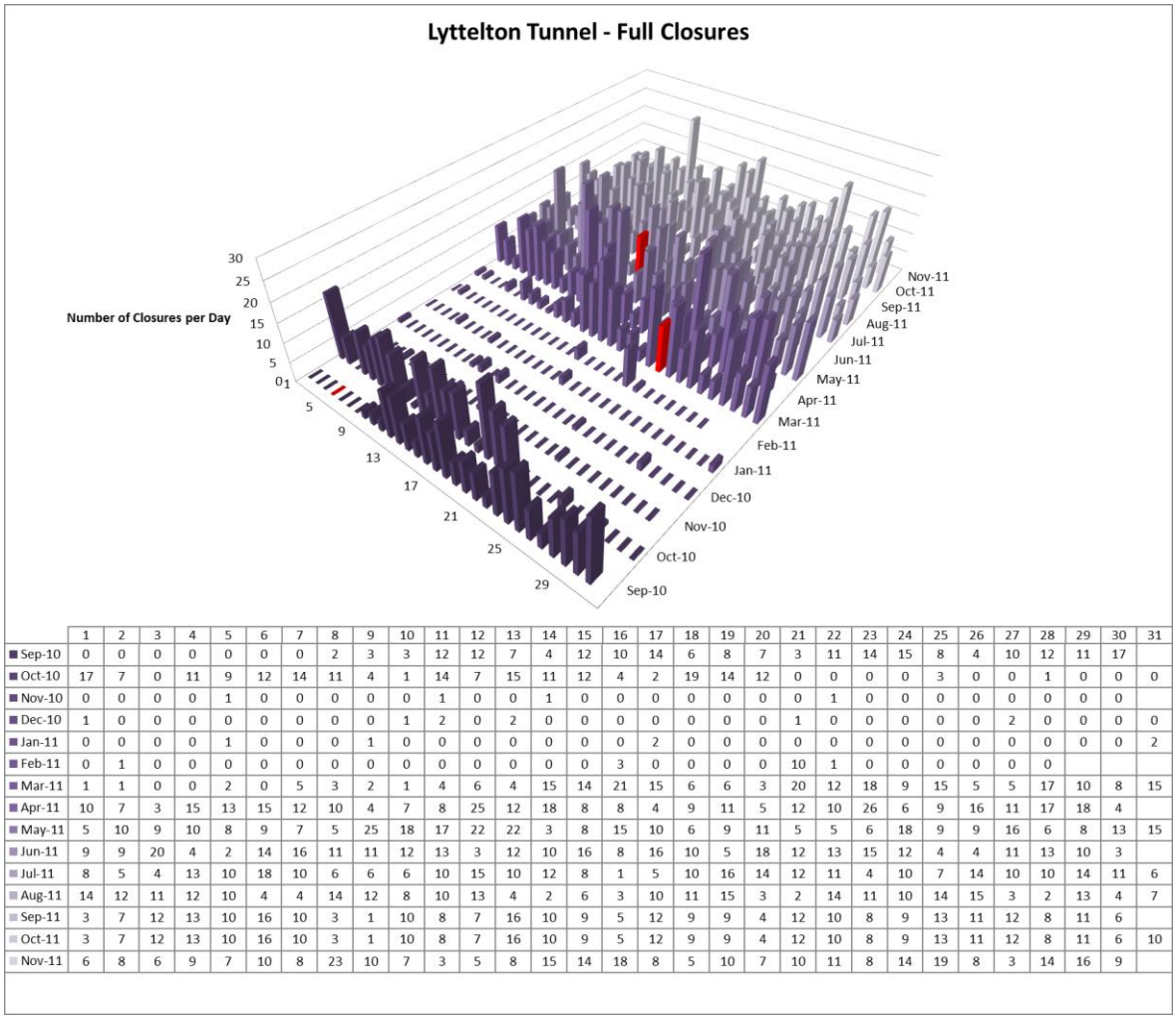
6.5.4 Lyttelton Road Tunnel Closures

The major route into and out of Lyttelton remains the Lyttelton road tunnel. After the Darfield Earthquake and Christchurch Earthquakes it was closed for detailed inspection, but also because the portals (especially at the Heathcote end) suffered damage. After each major aftershock, it was closed for a visual inspection before traffic was allowed to pass (NZTA 2010-2011).

The tunnel was also closed whilst scaling work on and around Castle Rock was happening.

The tunnel control building and toll booth gantry structure were damaged in the Darfield Earthquake and put beyond use in the Christchurch Earthquake (NZTA 2011b): they have since been demolished.

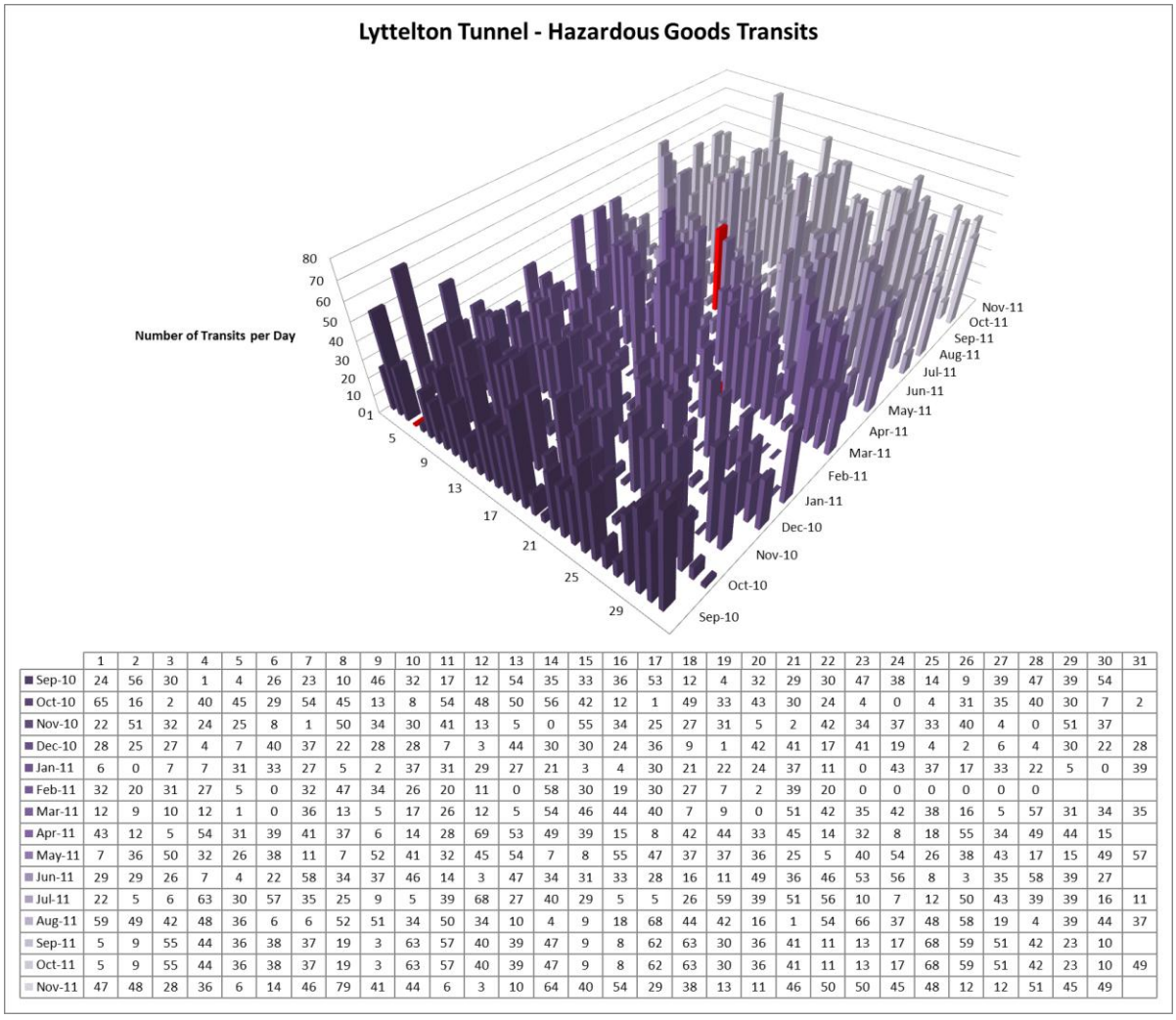
The Lyttelton road tunnel was open only to emergency services and special goods transit to and from the Port after the major earthquakes. After three days access was opened to restricted use by the residents of Lyttelton (NZTA 2011a), and much later it opened to public access (NZTA 2011b).



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Sep-10	0	0	0	0	0	0	0	2	3	3	12	12	7	4	12	10	14	6	8	7	3	11	14	15	8	4	10	12	11	17	
Oct-10	17	7	0	11	9	12	14	11	4	1	14	7	15	11	12	4	2	19	14	12	0	0	0	0	3	0	0	1	0	0	0
Nov-10	0	0	0	0	1	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	
Dec-10	1	0	0	0	0	0	0	0	0	1	2	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0
Jan-11	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Feb-11	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	10	1	0	0	0	0	0	0			
Mar-11	1	1	0	0	2	0	5	3	2	1	4	6	4	15	14	21	15	6	6	3	20	12	18	9	15	5	5	17	10	8	15
Apr-11	10	7	3	15	13	15	12	10	4	7	8	25	12	18	8	8	4	9	11	5	12	10	26	6	9	16	11	17	18	4	
May-11	5	10	9	10	8	9	7	5	25	18	17	22	22	3	8	15	10	6	9	11	5	5	6	18	9	9	16	6	8	13	15
Jun-11	9	9	20	4	2	14	16	11	11	12	13	3	12	10	16	8	16	10	5	18	12	13	15	12	4	4	11	13	10	3	
Jul-11	8	5	4	13	10	18	10	6	6	6	10	15	10	12	8	1	5	10	16	14	12	11	4	10	7	14	10	10	14	11	6
Aug-11	14	12	11	12	10	4	4	14	12	8	10	13	4	2	6	3	10	11	15	3	2	14	11	10	14	15	3	2	13	4	7
Sep-11	3	7	12	13	10	16	10	3	1	10	8	7	16	10	9	5	12	9	9	4	12	10	8	9	13	11	12	8	11	6	
Oct-11	3	7	12	13	10	16	10	3	1	10	8	7	16	10	9	5	12	9	9	4	12	10	8	9	13	11	12	8	11	6	10
Nov-11	6	8	6	9	7	10	8	23	10	7	3	5	8	15	14	18	8	5	10	7	10	11	8	14	19	8	3	14	16	9	

Figure 6-19 : Lyttelton Road Tunnel - Full Closures (NZTA 2010-2011)

Due to Evans Pass being closed, hazardous goods traffic (petroleum, LPG, etc.) are being diverted through the tunnel, necessitating closure during the transit. Wide loads also require the tunnel to be closed in one direction.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Sep-10	24	56	30	1	4	26	23	10	46	32	17	12	54	35	33	36	53	12	4	32	29	30	47	38	14	9	39	47	39	54	
Oct-10	65	16	2	40	45	29	54	45	13	8	54	48	50	56	42	12	1	49	33	43	30	24	4	0	4	31	35	40	30	7	2
Nov-10	22	51	32	24	25	8	1	50	34	30	41	13	5	0	55	34	25	27	31	5	2	42	34	37	33	40	4	0	51	37	
Dec-10	28	25	27	4	7	40	37	22	28	28	7	3	44	30	30	24	36	9	1	42	41	17	41	19	4	2	6	4	30	22	28
Jan-11	6	0	7	7	31	33	27	5	2	37	31	29	27	21	3	4	30	21	22	24	37	11	0	43	37	17	33	22	5	0	39
Feb-11	32	20	31	27	5	0	32	47	34	26	20	11	0	58	30	19	30	27	7	2	39	20	0	0	0	0	0	0			
Mar-11	12	9	10	12	1	0	36	13	5	17	26	12	5	54	46	44	40	7	9	0	51	42	35	42	38	16	5	57	31	34	35
Apr-11	43	12	5	54	31	39	41	37	6	14	28	69	53	49	39	15	8	42	44	33	45	14	32	8	18	55	34	49	44	15	
May-11	7	36	50	32	26	38	11	7	52	41	32	45	54	7	8	55	47	37	37	36	25	5	40	54	26	38	43	17	15	49	57
Jun-11	29	29	26	7	4	22	58	34	37	46	14	3	47	34	31	33	28	16	11	49	36	46	53	56	8	3	35	58	39	27	
Jul-11	22	5	6	63	30	57	35	25	9	5	39	68	27	40	29	5	5	26	59	39	51	56	10	7	12	50	43	39	39	16	11
Aug-11	59	49	42	48	36	6	6	52	51	34	50	34	10	4	9	18	68	44	42	16	1	54	66	37	48	58	19	4	39	44	37
Sep-11	5	9	55	44	36	38	37	19	3	63	57	40	39	47	9	8	62	63	30	36	41	11	13	17	68	59	51	42	23	10	
Oct-11	5	9	55	44	36	38	37	19	3	63	57	40	39	47	9	8	62	63	30	36	41	11	13	17	68	59	51	42	23	10	49
Nov-11	47	48	28	36	6	14	46	79	41	44	6	3	10	64	40	54	29	38	13	11	46	50	50	45	48	12	12	51	45	49	

Figure 6-20 : Lyttelton Road Tunnel - Hazardous Goods Transits (NZTA 2010-2011)

6.6 Regarding the February 2010 tsunami

The 2010 survey used the tsunami at the end of February 2010 as a base line for a natural hazard that could affect the population of the study area. Of the 81 responses, 7 related having experienced a tsunami before: four of those replies referred to the February 2010 tsunami in Lyttelton Harbour; one referred to the 1960 tsunami in Lyttelton; one referred to the 2004 Indonesian tsunami; and, one did not provide details.

119 responses were received regarding the actions of participants during the time of the February 2010 tsunami (Table 6-6).

Table 6-6 : Reaction to the tsunami of February 2010

Reaction to the tsunami 2010		
	Count	Column % Valid N
Didn't know it was happening	9	8%
Found out too late to evacuate, so stayed at home	4	3%
Stayed at home because house was high enough to not worry	62	52%
Self-evacuated to higher ground	3	3%
Went to the harbour to look out for the wave	1	1%
Went up to Summit Road to watch	1	1%
Went about normal business	29	24%
Did not live in the area at the time	3	3%
Other	7	6%
	119	100%

Participants also described the tsunami in their own words:

Table 6-7 : Descriptions of the February 2010 tsunami experiences

Description of tsunami actions
Came back to Lyttelton from Pigeon Bay before 8am arrival due to avoid being trapped by road closures/bridge washouts. Happened to hear 3am news, so forewarned. Phoned neighbours in low lying houses in case they had not heard.
Don't remember
Had car parked and pointed up hill (25m+)
Kept listening to media reports + watching harbour
Learnt about it too late after tsunami had affected areas in Port of Lyttelton
On holiday in Marlborough Sounds
Stayed at home and conducted our normal lives
Walking Taylor's Mistake and finding all these people looking out for the wave
Was on our boat - put out to sea for the day
Was prepared to leave (as live right by the sea)
Watched out
Watched the harbour from home in Lyttelton
We lived at Waikuku Beach, had car ready to go, listened to radio

6.7 Survey comments review

From the comments received from the participants of the 2011 survey, there was a theme of feeling cut off from Christchurch. Residents were anxious for their friends and relatives in the affected eastern suburbs but couldn't get through as all exits were blocked or closed. Likewise, people's attempts in trying to get to Lyttelton to help relatives were stressful for all concerned:

"We are two elderly folk in their eighties, and cause concern and danger to our families in reaching us with both passes blocked and tunnel closed in an emergency" – reply from 2011 Survey

Lyttelton is very dependent on the Lyttelton road tunnel, more than ever since Evan's Pass Road is still closed. Some residents still do not want to pass through it, though, and prefer to drive over Dyers Pass Road.

It was very apparent in February that the congestion after such a large event took emergency services by surprise.

"The lack of communication about which routes we could used to get home from the city to Lyttelton caused a hassle. / Initially we drove to Sumner. / Finally Police there were able to say that Dyers Pass was open. Police at Cashmere High didn't have that" – reply 2011 Survey

People's situation and expectations had changed by the Sumner Earthquakes and the journey times were halved.

The public transport system was shut down just when people needed it to evacuate to their homes, as they had to leave cars behind under collapsed buildings or impassable streets.

"Feel that there hasn't been enough effort made to reinstate what was an excellent public transport system. In 10 years we have only used a car once a week. Now we are using 2 cars a day! This is only because the bus frequency has been reduced so that Lyttelton to the airport and back now takes a large chunk on the day which is ridiculous. While it might sound insignificant it causes much more congestion on the roads and reduces people's, particularly children and the elderly, options." - reply from 2011 Survey

Where vehicles could be used, due to the damage and destruction to roads and bridges, congestion became an immediate issue. Emergency services seeking to rescue people were diverted from crowd control and traffic management: members of the public took it upon themselves to act as best they could to help manage the situation:

"…Husband at … time of quake he was on ferrymead bridge. He had to redirect traffic." – reply 2011 Survey

7 Actions of affected households

7.1 Evacuations - Planning vs. Actions

The 2010 survey asked respondents for likely scenarios concerning evacuation or sheltering in place after a large disaster had struck the area: whether they would evacuate (and how) or whether or not they would stay (and why). The 2011 survey asked respondents whether their household evacuated or stayed at home for both the Christchurch and Sumner Earthquakes. It recorded the reasons for evacuating and destination, when they evacuated and for how long. If they stayed at home, it recorded whether it was through choice or necessity.

7.1.1 Comparison of anticipated action if a disaster were to occur with actual actions – 2010 survey vs. 2011 survey

In 2010, 24% of respondents answered that they anticipate they would self-evacuate at least one member of their household from their home, even if structurally sound, yet critical services (water, power, telephone) were disrupted, to somewhere outside of the affected area within the first three days of the disaster unfolding.

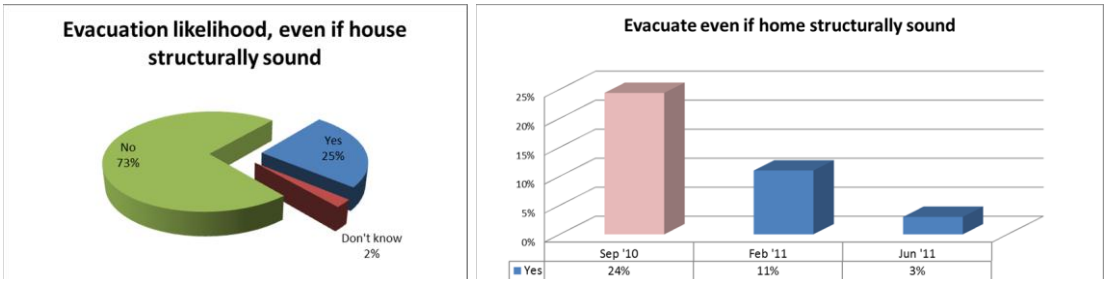


Figure 7-1 : Comparison of anticipated (left) and actual evacuation (right) decision, even if home still structurally sound

As events transpired, only 11% of respondents evacuated one or more of their household due purely to loss of services in February, falling to 3% in June (Figure 7-1).

The 2010 survey asked respondents their anticipated actions should their home suffer structural damage (Figure 7-2). Two-thirds (67%) of respondents in 2010 replied that they would evacuate their home if it was structurally unsound, but in February only a half (51%) of households had decided to evacuate at least one member in those circumstances, and in

June this had fallen to 15%. A quarter (25%) of those surveyed in 2010 anticipated that they would evacuate some from their household, even if the home suffered no structural damage, this climbing to a third (32%) after the Christchurch Earthquake, and falling to one-fifth (18%) in June after the Sumner Earthquakes.

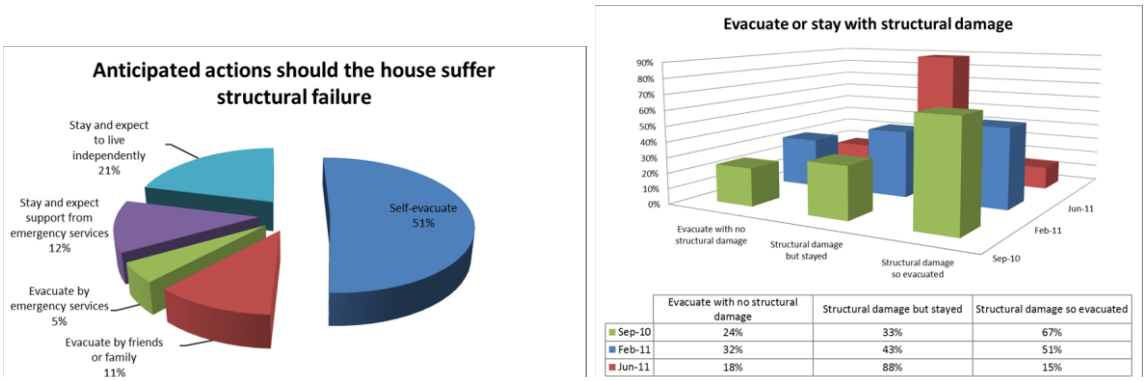


Figure 7-2 : Anticipated evacuation plans (2010 survey) (left) and (right) actions with structurally damaged home

7.1.2 Comparison of actions after the Christchurch and Sumner Earthquakes

The 2011 survey afforded the respondents the opportunity of categorising how they evacuated or why they stayed. It was also possible to detect when households split, with some staying (either to guard the property or to have a base from which to go to work from) and the others evacuating (due to stress, because they didn't think it safe, or because they lacked creature comforts).

Respondents had three alternatives to the reason why they stayed at home:

- Wanted to — There was no reason for them to stay other than their personal preference.
- Needed to — There was an external factor affecting their decision to evacuate. For example, they may have had to look after a dependent (an elderly household member or neighbour that didn't want to evacuate, pet), or they needed to stay in the region and couldn't evacuate.
- Had to — They did not have a decision to make. For example, they were a dependent and had to stay with their guardian, they perceived they had no alternative accommodation, they could not afford to evacuate,

or they could not evacuate because they were tenants and had to pay rent, even if they evacuated.

In February, 527 (42.8%, N=1229) people from 226 (43.3%, N=520) households evacuated (refer to Table 7-1): 320 (60.7%, N=527) people evacuated on their own, 137 (26.0%, N=527) were evacuated by friends or family, and 70 (13.3%, N=520) people were evacuated by the emergency services. 695 (56.6%, N=1229) people stayed at home from 332 (63.8%, N=520) households: 643 (92.5%, N=695) stayed at home of their own choice, 28 (4.0%, N=695) had to stay to care for others, and 24 (3.6%, N=695) had nowhere else to go. 7 (0.5%, N=1229) people did not answer the question. 188 (36.2%, N=520) households evacuated as a whole, 294 (56.5%, N=520) households stayed at home together, and 38 (7.3%, N=520) households split.

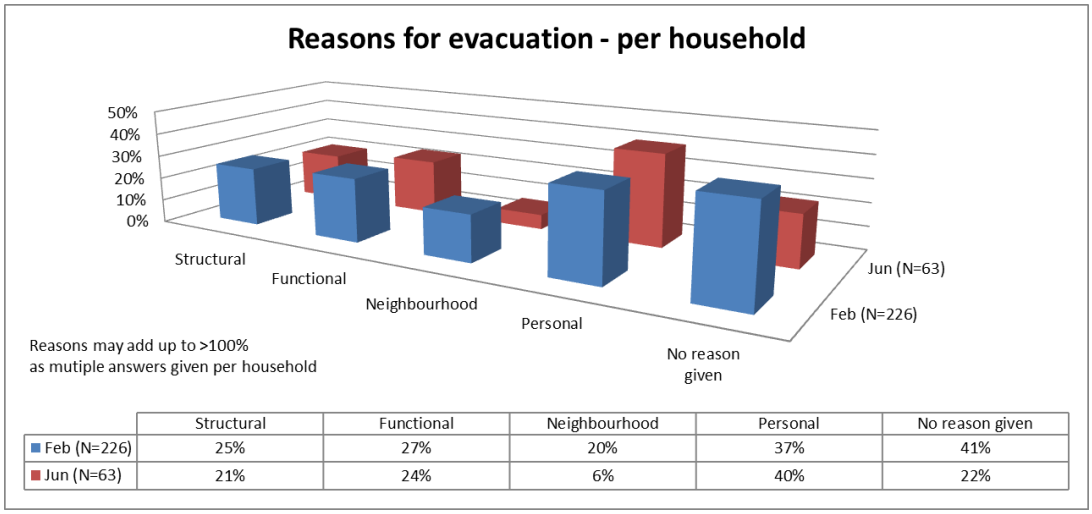
Table 7-1 : February 2011 - individual responses to evacuation or stay at home

		February *N=1222*	February %	June *N=1229*	June %
Evacuated	By self	320	26%	106	9%
	By friends/family	137	11%	24	2%
	By emergency services	70	6%	6	0%
Stayed	Wanted to	643	53%	1045	85%
	Needed to	28	2%	31	3%
	Had to	24	2%	17	1%

In June, 136 (11.1%, N=1229) people from 63 (12.1%, N=520) households evacuated: 106 (77.9%, N=136) people evacuated on their own, 24 (17.6%, N=136) were evacuated by friends or family, and 6 (4.4%, N=136) people were evacuated by the emergency services. 1093 (88.9%, N=1229) people stayed at home from 468 (90.0%, N=520) households: 1045 (95.6%, N=1229) stayed at home of their own choice, 31 (2.8%, N=1093) had to stay to care for others, and 17 (1.5%, N=1093) had nowhere else to go. 52 (10.0%, N=520) households evacuated as a whole, 457 (87.8%, N=520) households stayed at home together, and 11 (2.1%, N=520) households split.

In total, 239 (45.9%, N=520) separate households evacuated both after the February and June events. 11 (2.1%, N=520) households that did not evacuate in February evacuated in June: 4 (36.4%, N=11) due to structural concerns for their home, 1 (9.1%, N=11) due to lack of utilities, and 6 (54.5%, N=11) for various personal reasons (work-related, stress, caring for others) or reason not given.

Analysis of the reasons to evacuate by individuals, normalised to their households, reveals that the most likely reason (when given) to evacuate is for personal reasons, for example because of stress, comfort, health, etc. (Figure 7-3).



	Structural	Functional	Neighbourhood	Personal	No reason given
Feb (N=226)	25%	27%	20%	37%	41%
Jun (N=63)	21%	24%	6%	40%	22%

Figure 7-3 : Reasons given for evacuation normalised to the level of a household - February (N=226) vs. June (N=63)

There was a very marked decrease in the number of evacuations after the Sumner Earthquake than recorded for the Christchurch Earthquake.

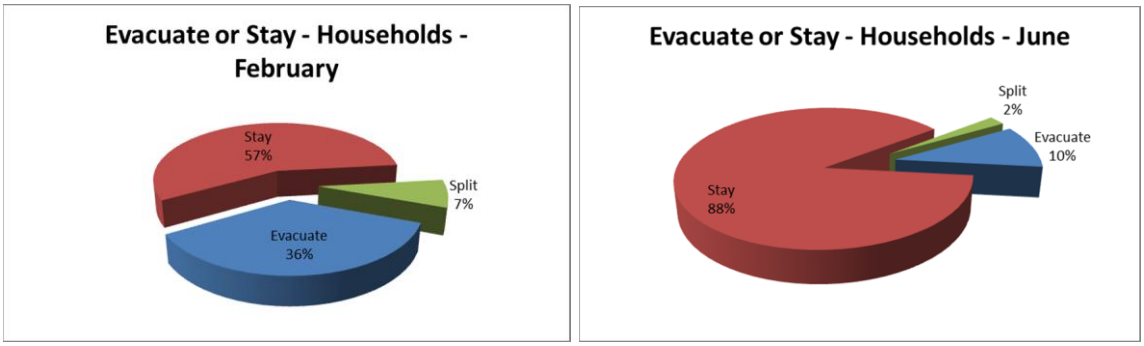


Figure 7-4 : Evacuate or stay (households) - February vs. June

7.1.2.1 Gender as a predictor to evacuate

It is not possible to ascertain the gender of individuals due to the construction of the questionnaire. However, it is possible to compare the relative male/female constitution of each household and relate that probabilistically to the number of evacuees and those that stayed home for each household:

Table 7-2 : Formulae for calculating the probabilistic outcomes of Male vs. Female - Evacuate vs. Stay

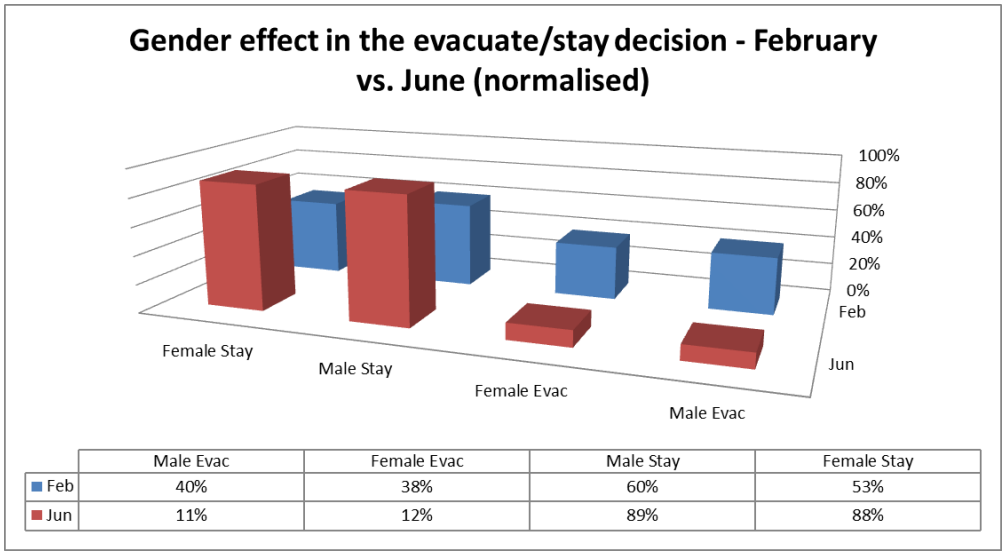
	Male	Female
Evacuate	$\sum_{1}^{n=520} \frac{(Number\ of\ Males \times Number\ of\ Evacuees)}{(Number\ of\ Evacuees + Number\ of\ Stays)}$	$\sum_{1}^{n=520} \frac{(Number\ of\ Females \times Number\ of\ Evacuees)}{(Number\ of\ Evacuees + Number\ of\ Stays)}$
Stay	$\sum_{1}^{n=520} \frac{(Number\ of\ Males \times Number\ of\ Stays)}{(Number\ of\ Evacuees + Number\ of\ Stays)}$	$\sum_{1}^{n=520} \frac{(Number\ of\ Females \times Number\ of\ Stays)}{(Number\ of\ Evacuees + Number\ of\ Stays)}$

The probabilities of the four results are then aggregated and an average probability derived for the four possible outcomes: Male Stay, Female Stay, Male Evacuate, and Female Evacuate.

By further normalising the values, such that the total evacuees and stays value 100% for the male and female groupings (i.e. *Male Evac* + *Male Stay* = 100%), a direct comparison can be made between genders.

A non-normalised value can be interpreted as: “out of the whole population, males that evacuated made up 19%”. If the value was not normalised, a bias of gender across the population would be introduced. A normalised value can be interpreted as: “of males in the population, 40% evacuated”.

The results show little to differentiate males and females and their actions after either of the Christchurch or Sumner Earthquakes (Figure 7-5). Gender is therefore not sufficient as a predictor on whether or not an individual would evacuate or stay at home.

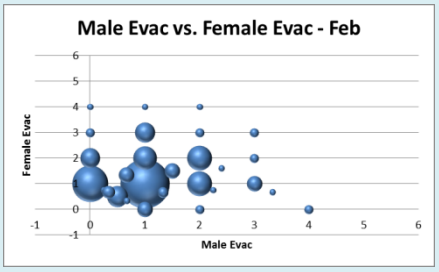
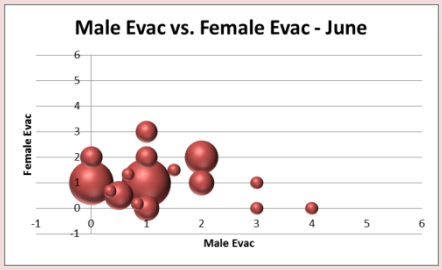
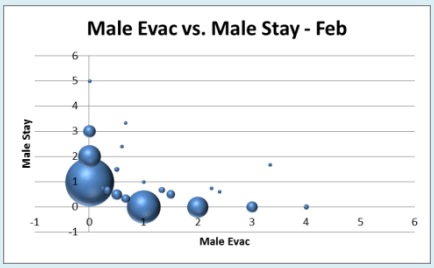
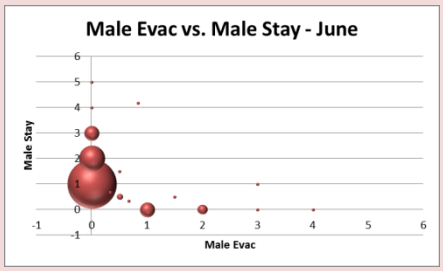
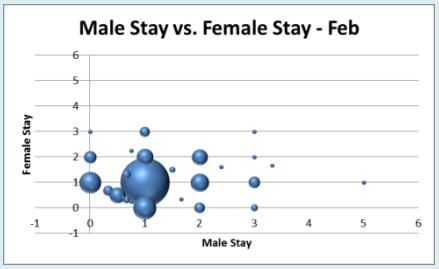
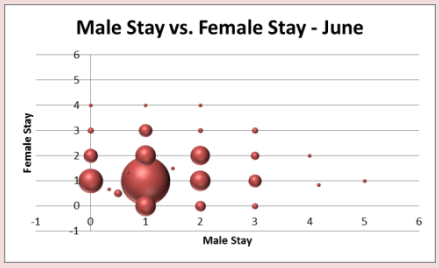
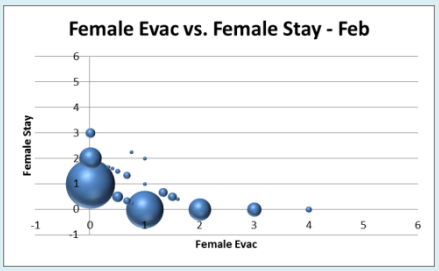
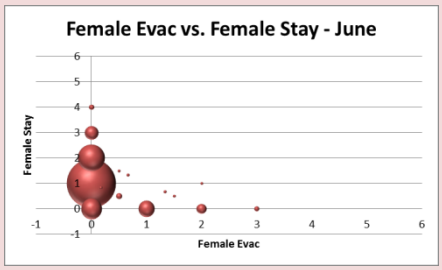


	Male Evac	Female Evac	Male Stay	Female Stay
Feb	40%	38%	60%	53%
Jun	11%	12%	89%	88%

Figure 7-5 : Gender as a predictor in the evacuation/stay decision - February vs. June

The generalised statistical analysis is quite a blunt instrument, so a weighted scatter-plot (bubble diagramme) was used to detect nuances in the behaviour between genders. Two variables out of the possible four (*Female Stay*, *Male Stay*, *Female Evac*, *Male Evac*) were compared and plotted as coordinates on the scatter plot. The number of times each coordinate was encountered in the sample (N=520) was recorded as the diameter of the bubble centred at that coordinate.

Even though the average percentage of males and females that evacuated in February, over the complete sample (N=520), is almost equal (40% vs. 38%), the scatter plot unveils nuances and subtleties of distribution of results that are otherwise hidden.

	February 2011	June 2011
Male evacuation vs. Female evacuation	 Figure 7-6 : Male Evac vs. Female Evac - Feb	 Figure 7-7 : Male Evac vs. Female Evac - June
Male evacuation vs. Male stay	 Figure 7-8 : Male Evac vs. Male Stay - Feb	 Figure 7-9 : Male Evac vs. Male Stay - June
Male Stay vs. Female Stay	 Figure 7-10 : Male Stay vs. Female Stay - Feb	 Figure 7-11 : Male Stay vs. Female Stay - June
Female Evac vs. Female Stay	 Figure 7-12 : Female Evac vs. Female Stay - Feb	 Figure 7-13 : Female Evac vs. Female Stay - June

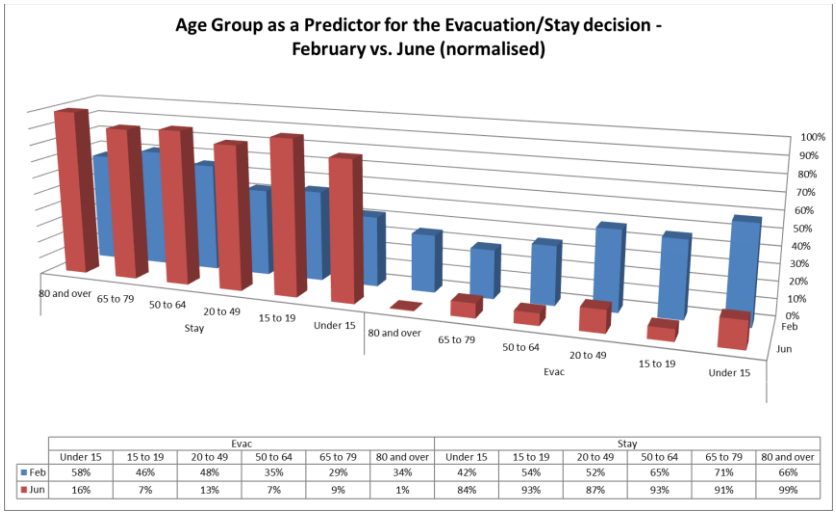
In February 2011, 40% of males in households evacuated compared to 38% of females. The majority were probably couples (large bubble in (1,1) in Figure 7-6). Figure 7-6 also appears to show that females would evacuate without males, whereas males were less likely to leave without females. The same pattern presents itself in June 2011, although there are less households with large numbers of individuals evacuating (maximum size N=4).

In February 2011, it was very probable that couples would stay (large bubble in (1,1) in Figure 7-10). In June 2011, again this pattern presents itself, but there are slightly more females staying and not evacuating.

7.1.2.2 Age Group as a predictor to evacuate

It is not possible to ascertain the age group of individuals due to the construction of the questionnaire. However, it is possible to compare the relative age group constitution of each household and relate that probabilistically to the number of evacuees and those that stayed home for each household. This is similar to the process used for gender (above), except that instead of two there are 6 possible groups.

Again, by further normalising the values, such that the total evacuees and stays value 100% for each of the 6 age groups, a direct comparison can be made between the age groups (Figure 7-14).



	Evac						Stay					
	Under 15	15 to 19	20 to 49	50 to 64	65 to 79	80 and over	Under 15	15 to 19	20 to 49	50 to 64	65 to 79	80 and over
Feb	58%	46%	48%	35%	29%	34%	42%	54%	52%	65%	71%	66%
Jun	16%	7%	13%	7%	9%	1%	84%	93%	87%	93%	91%	99%

Figure 7-14 : Age Group as a Predictor for the Evacuation/Stay decision - February vs. June (normalised)

In February, after the Christchurch Earthquake, the younger age group an individual falls into predicts the evacuation outcome. This correlation is not so obvious in June, after the Sumner Earthquake.

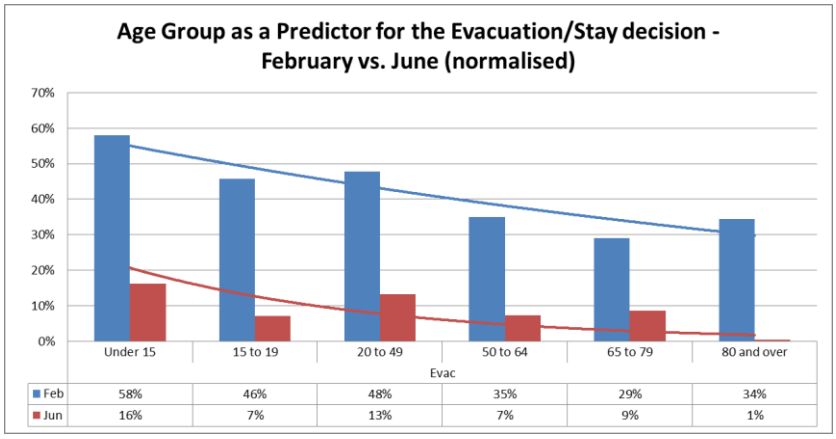
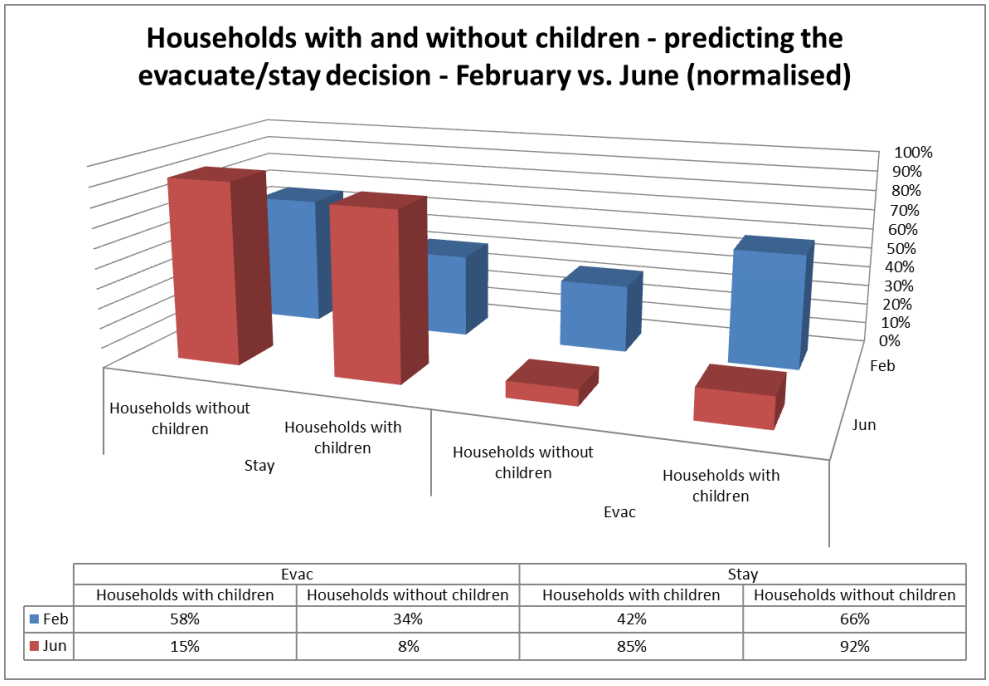


Figure 7-15 : Age group as predictor of evacuation - February vs. June (normalised) - trends

7.1.2.3 Households with children vs. without as predictor to evacuate

The numbers of households with and without children have been normalised to make comparisons easier. It is apparent that after the Christchurch Earthquake, 58% of households with children evacuated compared with almost half of that number (34%) of households without children (Figure 7-16).

In June, again, almost twice as many households with children (15%) evacuated than those without children (8%), yet, even so, only a quarter of the number when compared with February (58% vs. 15%).



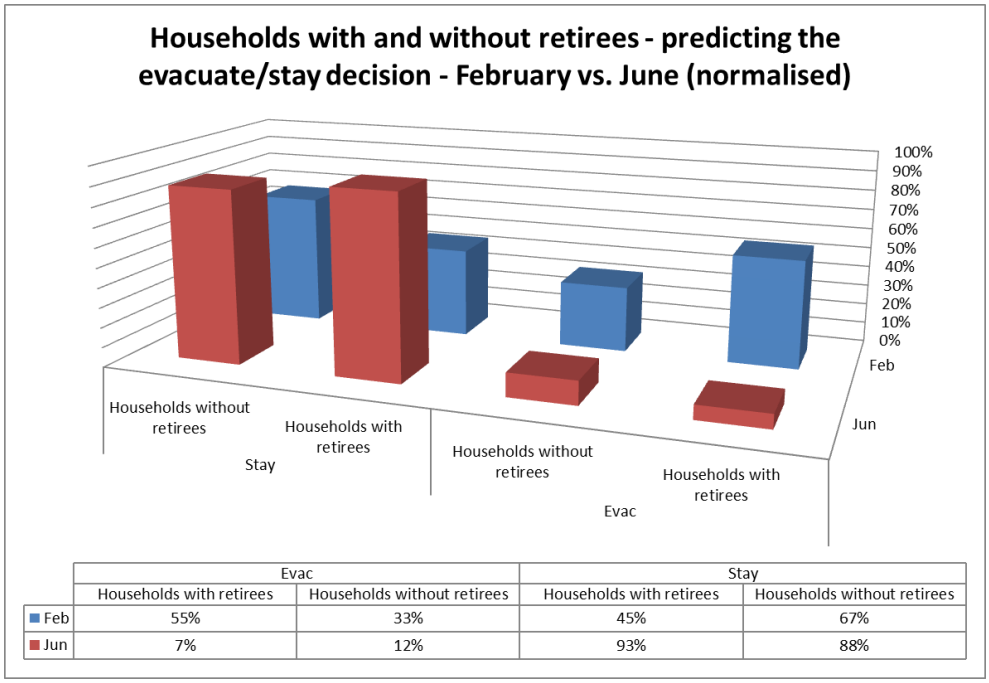
	Evac		Stay	
	Households with children	Households without children	Households with children	Households without children
Feb	58%	34%	42%	66%
Jun	15%	8%	85%	92%

Figure 7-16 : The presence of children in the household as a predictor for evacuation - February vs. June (normalised)

7.1.2.4 Households with retirees vs. without as predictor to evacuate

The numbers of households with and without retirees have been normalised to make comparisons easier. It is apparent that after the Christchurch Earthquake, 55% of households with retirees evacuated compared with two-fifths of that number (33%) of households without retirees (Figure 7-17).

In June, just over a half of those households with retirees (7%) evacuated, compared to those without (12%), an eighth of the number from February. Of the 11 households that permanently evacuated after February, only 1 had retirees. That household accounted for 2 retirees and one child.



	Evac		Stay	
	Households with retirees	Households without retirees	Households with retirees	Households without retirees
Feb	55%	33%	45%	67%
Jun	7%	12%	93%	88%

Figure 7-17 : The presence of retirees in the household as a predictor for evacuation - February vs. June (normalised)

7.1.2.5 Household size as predictor to evacuate

Table 7-3 : February 2011 - individual responses to evacuation or stay at home - per household size

		Household Size						
		1	2	3	4	5	6	All
Evacuated	By self	25	94	71	99	15	16	320
	By friends/family	11	29	31	50	15	1	137
	By emergency services	3	34	14	13		6	70
Stayed	Wanted to	57	316	127	114	10	19	643
	Needed to		7	9	12			28
	Had to	3	10	3	8			24

Table 7-4 : June 2011 - individual responses to evacuation or stay at home - per household size

		Household Size						
		1	2	3	4	5	6	All
Evacuated	By self	14	29	24	38		1	106
	By friends/family	2	7	2	13			24
	By emergency services		2		4			6
Stayed	Wanted to	81	436	221	232	40	35	1045
	Needed to		4	8	13		6	31
	Had to	2	12	3				17

When comparing the size of households that stay and those that evacuate, there appears to be a trend in February that the larger the household the more likely they were to have evacuated (Figure 7-18). This trend was reversed in June.

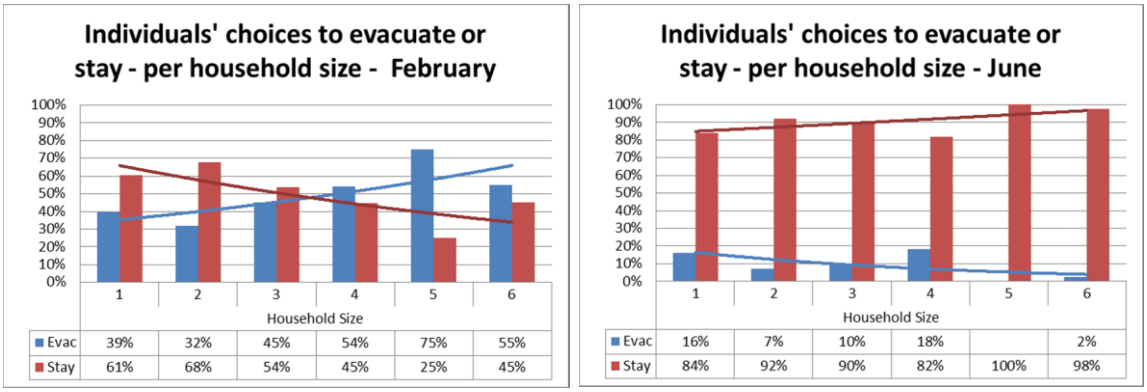
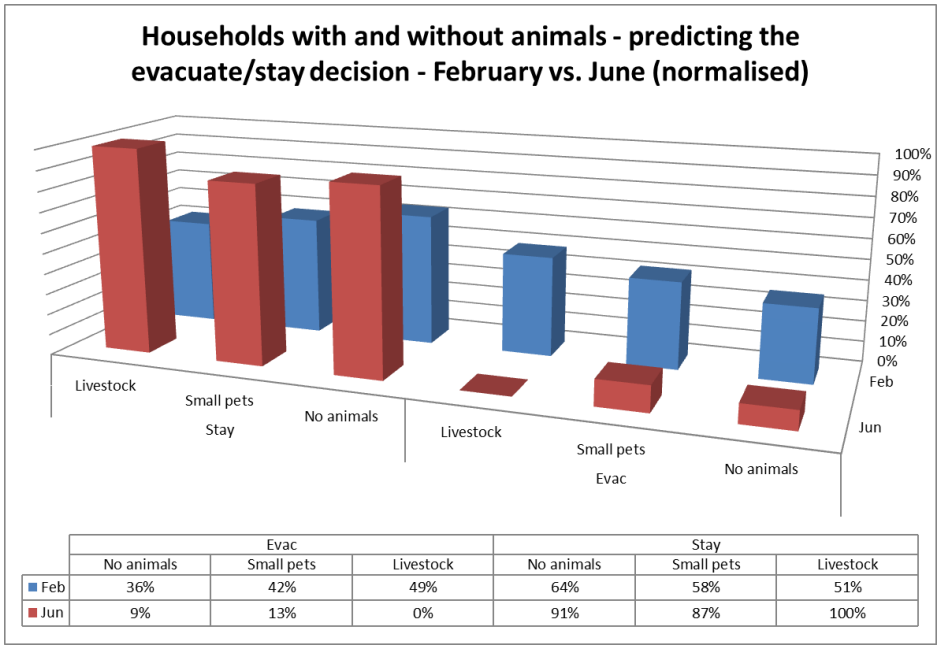


Figure 7-18 : Comparison of decision by individuals to evacuate or stay vs. household size – February/June (all results normalised)

7.1.2.6 Households with animal vs. without as predictor to evacuate

The numbers of households with and without animals have been normalised into three groups to make comparisons easier: those with no animals; those with small pets; and, those with livestock. After the Christchurch Earthquake there is a very slight correlation between caring for livestock and evacuation (Figure 7-19). This is not apparent in June.



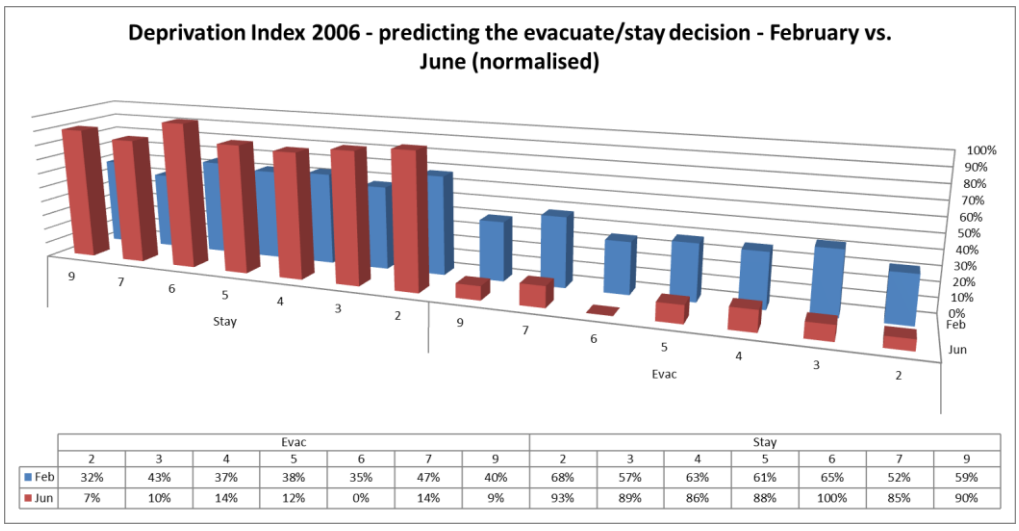
	Evac			Stay		
	No animals	Small pets	Livestock	No animals	Small pets	Livestock
Feb	36%	42%	49%	64%	58%	51%
Jun	9%	13%	0%	91%	87%	100%

Figure 7-19 : Households with animals as a predictor for evacuation - February vs. June (normalised)

One respondent with livestock noted that, even though they had a 3000 litre water tank, it was contaminated with town water supply and could not be used to water the animals. The fire brigade could not help, so an alternative was found by trucking 500 litres of muddy water per day from Living Springs.

7.1.2.7 Deprivation Index as a predictor to evacuate

The Deprivation Index 2006 has been used to normalise the households into 7 groups to make comparisons easier (Figure 7-20).



	Evac							Stay						
	2	3	4	5	6	7	9	2	3	4	5	6	7	9
Feb	32%	43%	37%	38%	35%	47%	40%	68%	57%	63%	61%	65%	52%	59%
Jun	7%	10%	14%	12%	0%	14%	9%	93%	89%	86%	88%	100%	85%	90%

Figure 7-20 : Deprivation Index 2006 as a predictor to evacuate - February vs. June (normalised)

There is no clear trend to decide whether or not the Deprivation Index 2006 influences the decision to evacuate. After the Christchurch Earthquake, households with a higher Deprivation Index were more likely to have a member evacuate, but this reversed after the Sumner Earthquakes. The trend to stay was flat for June, with a very slight and probably not significant trend to not stay for individuals in households with a higher Deprivation Index.

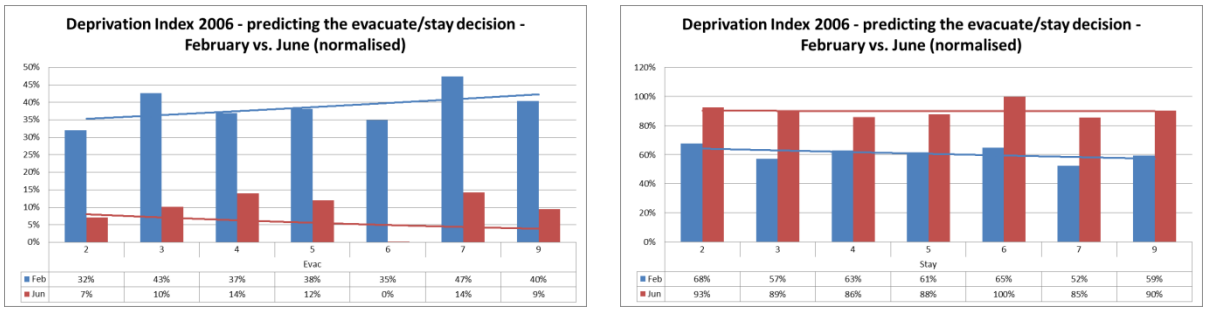
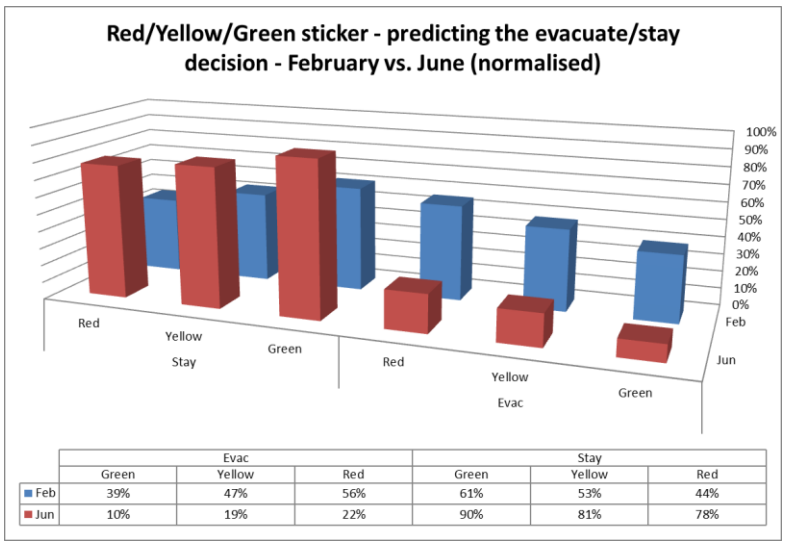


Figure 7-21 : Comparison Deprivation Index 2006 as predictor for evacuation (left) and stay (right) – February/June – trends

These results point to the Deprivation Index 2006 not being a significant predictor of the decision to evacuation.

7.1.2.8 Red/yellow/green stickers as predictor to evacuate

The numbers of households with red/yellow/green rapid assessment placards (stickers) have been normalised into three groups to make comparisons easier: those with red stickers; those with yellow stickers; and, those with green or no stickers (Figure 7-22).



	Evac			Stay		
	Green	Yellow	Red	Green	Yellow	Red
Feb	39%	47%	56%	61%	53%	44%
Jun	10%	19%	22%	90%	81%	78%

Figure 7-22 : Households with red/yellow/green sticker as a predictor for evacuation - February vs. June (normalised)

It is clear to see that there is a positive correlation between evacuating and red stickers, and staying and green stickers (Figure 7-23).

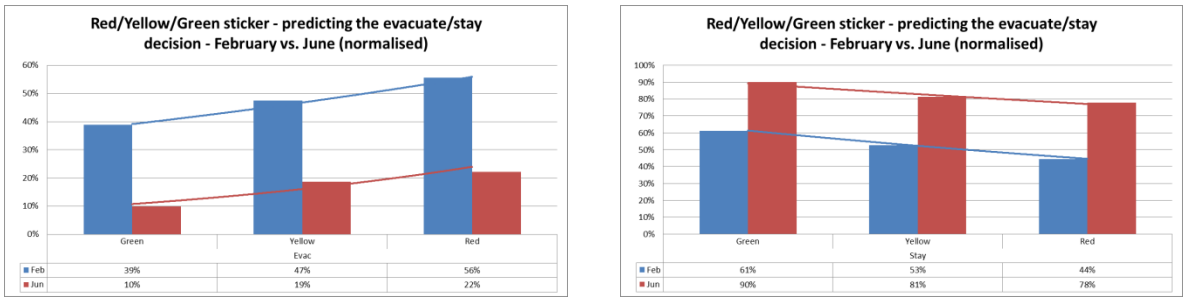


Figure 7-23 : Comparison of red/yellow/green placard as predictor for evacuation (left) and stay (right) – February/June – trends

***Note**: this analysis is very tenuous. Because of the time it takes for a rapid building assessment to be performed, it is likely that people would either not wait in order to evacuate, or would continue to live in their properties without knowing the structural integrity. The 2011 survey specifically limits the times in which an evacuation related to the Christchurch and Sumner Earthquakes, which means that outside of this time, the building could be red-stickered.*

7.2 Destinations

In February, 487 people were evacuated to 108 destinations. 203 evacuated to suburbs within Christchurch; 284 evacuated to destinations outside of Christchurch, including 13 overseas destinations (Australia, UK).

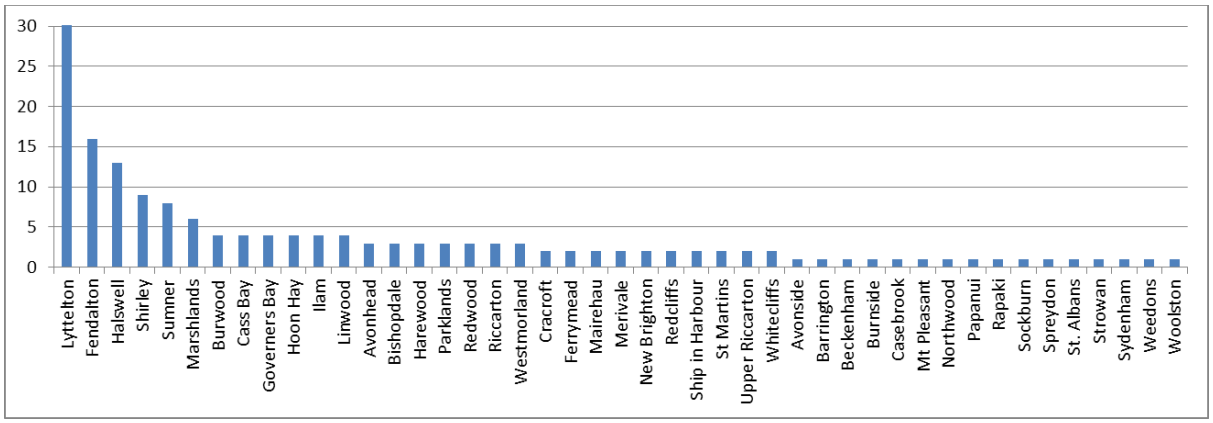


Figure 7-24 : February evacuation destinations within Christchurch (Lyttelton = 70)

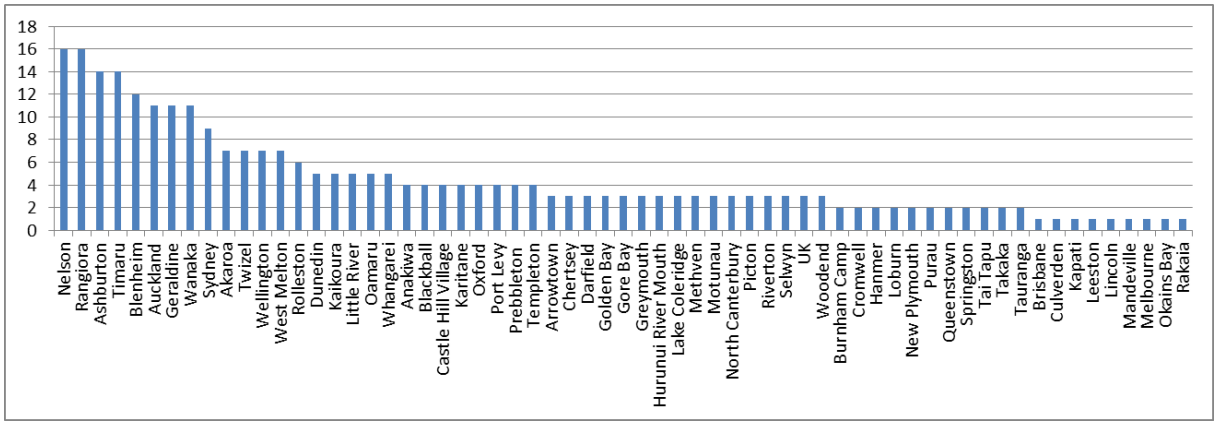


Figure 7-25 : February evacuation destinations outside of Christchurch

In June, 127 people were evacuated to 43 destinations. 60 evacuated to suburbs within Christchurch; 67 evacuated to destinations outside of Christchurch, including 2 overseas destinations (Australia, France).

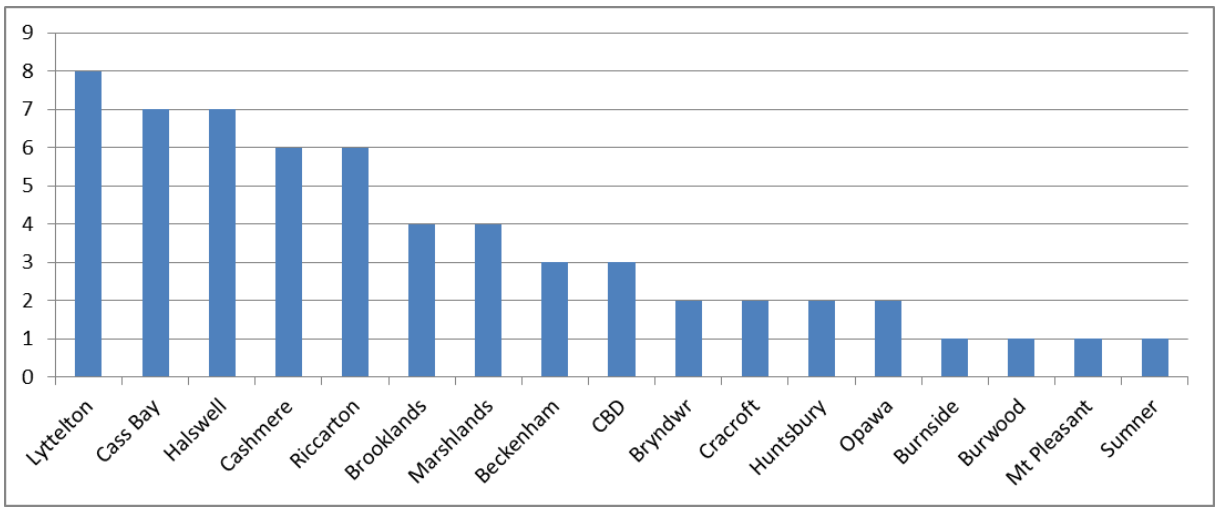


Figure 7-26 : June evacuation destinations within Christchurch

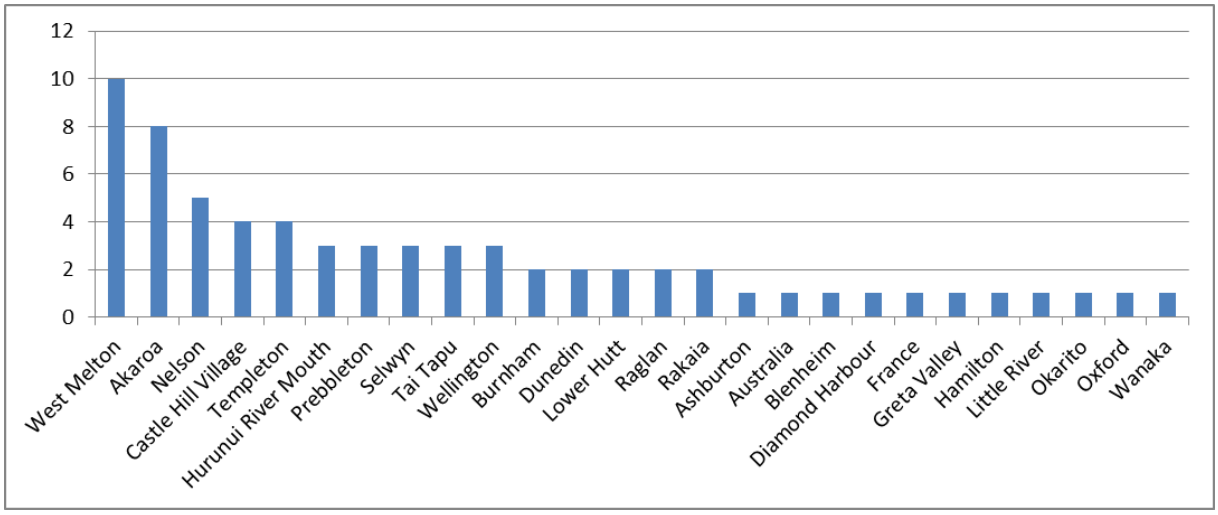


Figure 7-27 : June evacuation destinations outside of Christchurch

7.3 Delay and duration

After the Christchurch Earthquake, the majority of individuals that evacuated did so immediately on 22nd February. Significant numbers of individuals also evacuated in the following four days. When compared with evacuations after the Sumner Earthquakes, the overwhelming majority of evacuations occurred on 13th June.

Evacuations in February lasted typically for just over a week, but again a significant number lasted for more the two weeks. A small number were permanent. In June, evacuations lasted typically less than a week. A small number of individuals evacuated for more than two week, and a very small number evacuated permanently.

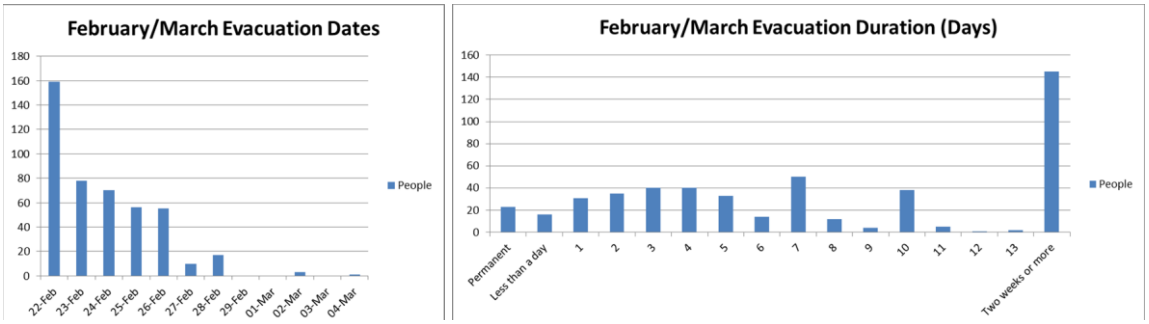


Figure 7-28 : Evacuation dates (vs. number of individuals) and durations – February/March

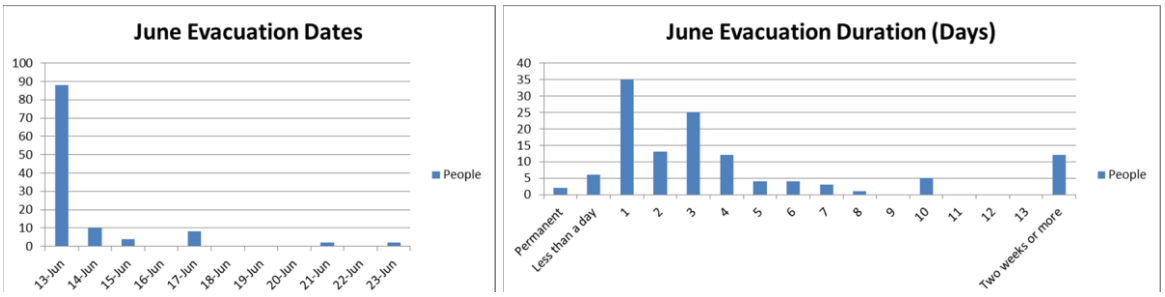


Figure 7-29 : Evacuation dates (vs. number of individuals) and durations – June

7.4 Emergency shelter and accommodation

The Department of Building and Housing (DBH) initially supplied 82 campervans on 14th March 2011 to the Canterbury Agricultural Park (Canterbury A & P Showgrounds) for use by those displaced by the Christchurch Earthquake from their own homes. By 1st April 2011, the number had risen to 350 campervans: 140 2-berth, 140 4-berth, and 70 6-berth (Robertson 2012). The campervans were not provided free of charge: the hire cost to the occupier was NZD 190 per week for a two-berth, NZD 271 for four-berth, and NZD 337 for six-berth. Renters were also required to pay a two-week bond and to pay for their own electricity and insurance (3 News 2011). The campervans were progressively returned over a period of time, the last being removed from site on 18th July 2012. During this period, of the 350 campervans made available, 5 were occupied (Robertson 2012):

2 x 2-berth – 15 April – 29 April 2011 and 9 May – 28 July 2011

2 x 4-berth – 10 June – 7 July 2011 and 10 June – 12 July 2011

1 x 6-berth – 20 May – 28 May 2011

A further 41 temporary 1-, 2-, 3-, and 4-bedroom houses were built at the Linwood Park Village, with rents set at NZD 190, NZD 271, NZD 337, NZD 423 respectively, with the first tenants moving in on 24th August 2011 (CCC 2011c). 22 of these houses have been occupied, with duration of tenancies ranging from 21 to 120 days (as of 6th January 2012) (Robertson 2012).

7.5 Structurally unsound yet still inhabited

Even when the home is structurally unsafe, people will attempt to stay (even if they are accommodated in their garage). The surroundings (neighbours and other support networks)

are familiar and people may be anxious to guard against burglars a property that is no longer secure. Children may be sent away to relatives for a short while whilst the parents are busy organising repairs.

There has been concern that the red, yellow, and green sticker system is being incorrectly applied to some earthquake-damaged buildings and causing confusion among owners (Barton 2011).

> *"People didn't understand what the red, yellow, green meant. They thought it was a structural check and it's not. It's an access guideline on whether people can go into buildings or not."* – Unitec Associate Professor Regan Potangaroa, RedR (Registered Engineers for Disaster Relief)

It is likely this misunderstanding has unfortunately led to people occupying green-stickered buildings that were in danger from being collapsed on by neighbouring red-stickered properties. Further, because a building was green-stickered did not mean it was safe given a further large aftershock. These lessons are being heard at the Canterbury Earthquakes Royal Commission of inquiry, which will report on the causes of building failure as a result of the Darfield and Christchurch Earthquakes as well as the legal and best-practice requirements for buildings in New Zealand Central Business Districts. The inquiry began in May 2011 (The Canterbury Earthquakes Royal Commission 2011).

7.6 Discussion

When people evacuated, the distance they moved has many factors associated with it: finding a locality that is perceived to be safe; the commuting distance to work; availability of accommodation; finances available; familiar surroundings. In June, only a quarter of the number of people that evacuated in February did so (not necessarily evacuating after both events). Just over a half tended to move outside of Christchurch.

The evacuate or stay decision is a very complex one: at the small scales used in this study, there are too many individual circumstances. The individuals' circumstances simply create noise and any weak predictor variable can be easily lost in that noise. The questionnaire was not the best instrument to sort through the nuances, and a formal, guided interview is perhaps the best approach to take.

The perception shift from before the Darfield Earthquake to after the Sumner Earthquake regarding evacuation is interesting: more households self-evacuated even though their home was structurally intact than they indicated in the 2010 survey (32% actually left but only 24% indicated they would). Also, fewer households evacuated (51%) when their home was structurally damaged than they indicated in the 2010 survey (67%). Could it be that, like those affected slightly in the Loma Prieta Earthquake (Mileti & O'Brien 1989), the population of Lyttelton were "normalised" to the Darfield Earthquake so the Christchurch Earthquake did not appear to be damaging enough to warrant evacuation? This may explain the June Earthquake evacuation statistics, where only 15% of households with structural damage self-evacuated. This may have been because of cumulative normalisation bias caused by both the Darfield and Christchurch Earthquakes.

No overly strong predictor variable was found, other than the colour of the sticker placard. As noted, the sticker is affixed after a period of time has passed and the occupants would have probably self-evacuated before that time: the sticker is therefore retrospective in making that evacuation decision. The occupier of a red-stickered house would have probably been able to sense the house was not safe and therefore left. A yellow-stickered house may have different justifications for being that colour and the occupier may have had a higher threshold to evacuate in that circumstance. Some may not want to leave the neighbourhood:

> *"I sleep in my Van where i have a mattress, bedding, water, and food" – reply from 2011 survey*

8 Research conclusions and further recommendations

The objectives of this research are to:

- Examine the preparedness of the resident population of Lyttelton and surrounding area for a natural or manmade disaster;
- Examine the vulnerability of the resident population of Lyttelton and surrounding area to impactful disaster; and,
- Examine the immediate response of the resident population of Lyttelton and surrounding area to recent disasters.

8.1 Preparedness

The majority of residents in Lyttelton to Rapaki are prepared for a disaster: they have sufficient provisions and community resilience to withstand a calamity for a minimum of three days. Lessons learned from the Darfield Earthquake have helped to guide many (not all) to be prepared.

Due to the short period between the recent and various events experienced by this study population, it has not been possible to distinguish if emotional distress from the first event in September 2010 has increased the preparedness for subsequent events, as proposed by (Siegel et al. 2003). From the initial results of the surveys, it appears as though the population was actually less prepared in 2011 than in 2010. Perhaps this was because the 2010 survey results showed the answers to be overly optimistic.

This is an interesting outcome, as the Darfield Earthquake should have made the residents more aware of the risk of earthquakes, and to prepare for them. Because the Darfield Earthquake did limited damage to buildings and shut down the lifelines infrastructure for a short while, this created a “normalisation bias” for non-victims. This bias limited their perception of risk to damaging aftershocks and protective response to warnings (Mileti & O'Brien 1989). The Darfield Earthquake may have tempered the population further, as 88% stayed in Lyttelton even though the Sumner Earthquake caused more damage to the buildings and infrastructure.

Certainly, the respondents had never had the opportunity to test whether or not they were prepared. It is suggested that the recent events should make a wide-scale ShakeOut exercise with participation from the general public more important for other parts of New Zealand that are prone to earthquakes, especially Wellington.

8.2 Vulnerability

The vulnerability of the population has probably reduced since the Canterbury Earthquake Sequence started, with each successive earthquake tending to shift rocks and boulders to lower energy levels. Chimneys and unsafe buildings have fallen by themselves. This warning to residents may have educated them to the dangers of living in or near older structures, and may have prompted them to move away from danger or change the risk environment by strengthening their property. All other building stock has been systematically checked, and then demolished or strengthened. This was not conceivable to do before the Darfield Earthquake as resources were not available: the Christchurch City Council had only required earthquake strengthening of buildings to bring them up to partial code only when significant alterations or change of use required a building consent(CCC 2010a).

Prior to the Canterbury Earthquake Sequence, the population of Lyttelton to Rapaki had been at risk of boulder roll and rockfalls from the steep slopes surrounding the residential areas (Elder et al. 1991). The Darfield Earthquake may have reduced the vulnerability to rockfall as people became aware of the dangers and the CCC sought to address the issue.

The Christchurch Earthquake, however, with a very shallow epicentre under the Port Hills, made any remediation work or mitigation efforts to date appear insignificant when compared to the amount of rock mobilised. Nevertheless, work has carried on to ground-truth boulder source and hazard areas (McFarlane 2011). In time, this work will make the Port Hills surrounding the study area safer, this reducing the physical source of the vulnerability of the population.

Lyttelton Harbour has an historical record of far-field tsunami inundating land close to the shoreline. The February 2010 tsunami was small (2m) in comparison to the 7m wave of 1868 that devastated the harbour (de Lange & McSaveney 2009; de Lange & Moon 2009). The

population is still at risk of such a wave (Power & Gale 2010). The communities of Cass Bay and Rapaki are sufficiently low-lying to be at risk of run-up.

The snows of 25th July 2011 closed Dyer's Pass Road for two days (CCC 2011a). The council spread sand on the steep slopes but when it melted the following weekend, it became very dangerous to drive and walk on (pers comms – the author). There is very little anyone can do to mitigate the effects of snow and ice in Lyttelton due to the very steep and narrow streets and the South-facing aspect which barely receives sun in the Winter. Snow clearing machinery is not effective due to the tight confines of most streets and the parked cars. The steepness of the slopes may make snow clearing dangerous, and the cleared streets would have the propensity of icing up overnight leading to a higher risk of accident in the morning.

8.3 Response

A constant theme throughout the comments from participants was the feeling of being cut-off as the tunnel, Evan's Pass, and Dyer's Pass Roads were closed. Families were divided as the routes through and around the Port Hills were closed. Many individuals attempted to travel from Sumner to Lyttelton by foot when they couldn't drive (survey). Others risked the fatal Bridle Path route (Mann 2011).

The homeward journey was halved in June when compared with February. It is suggested that residents had become familiar with driving on roads with many defects and detours. They make more-informed decisions on where to park (so access to their car is more certain after an event). The Christchurch Earthquake unexpectedly closed all of the routes into and leaving Lyttelton whereas closures after the Sumner Earthquakes were anticipated and routes altered.

As voice telecommunications were overloaded people turned to the Short Message Service (SMS) and started TXTing their family members. This lead to further overloading of the network: some TXTs were received after a long delay, which made making arrangements to meet difficult and, as the network is designed to drop these messages in extremes, there is no guarantee of delivery. Overall, the infrastructure handled the traffic well, but power outages required a quick deployment of electrical generators by Telecom, Vodafone and 2°

network engineers to cellular tower sites to keep the system running. The communication companies requested calls be limited in order to help preserve battery power in the interim.

The vulnerability of children and retirees need to be further analysed. Whilst parents expect the school will keep their children safe, the teachers and support staff themselves may be parents, wishing to reunite with their own children and families. This is all the more pressing if the children and parents are on opposite sides of the Port Hills with no safe route between. Throughout this, children must be kept in a low-stress environment that will reduce psychological trauma.

8.4 Further research

It is suggested that further research on how schools manage their relationships with students and caregivers/parents in the event of an emergency be undertaken. This is especially more important given the frequency in which Lyttelton is cut-off from north of the Port Hills where many children go to school or parents are at work.

The effects evacuation has on children (social upheaval, separation angst, etc.) should be compared with the effects staying in a place that may have bad memories and continuing aftershocks has.

The evacuation decision model (Chang et al. 2009; Wright & Johnston 2010) is perhaps not suitable for the small community of Lyttelton and the surrounding area in the study. Could a less macro-oriented and more micro-oriented model be designed? Are there any more predictor variables that are easily visible from outside of the household?

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B. Pre-September 2010 survey

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Natural Hazards Research Centre

Department of Geological Sciences

INFORMATION

You are invited to participate as a subject in a research project investigating the role of population movement in hazard management, preparedness, and mitigation, in the study area between Lyttelton and Rapaki.

Your involvement in this project will be to complete a 15-minute questionnaire.

The project is being carried out as a requirement for the Degree of Master of Science, Hazard and Disaster Management, by Julian Idle, under the supervision of Dr. Thomas Wilson, who can be contacted at 03 364 2987 Ext 45511, and Associate Professor Tim Davies, who can be contacted at 03 364 2987 Ext 7502. They will be pleased to discuss any concerns you may have about participation in the project.

By completing the questionnaire it will be understood that you have consented to contribute to the study, and that you consent to publication of the results of the project with the understanding that anonymity will be preserved.

The results of the project will be published as part of a thesis, but you may be assured of the complete confidentiality of data gathered in this investigation. To ensure anonymity and confidentiality, the returned completed questionnaire will only be handled by the principal researcher. The questionnaires will be identified by a unique number. All material will be handled and stored in a secure environment.

Please return the completed questionnaire using the stamped, self-addressed envelope provided.

The project has been reviewed ***and approved*** by the University of Canterbury Human Ethics Committee.

Principal researcher: Julian Idle (julian.idle@pg.canterbury.ac.nz)
Supervisor: Dr. Thomas Wilson (thomas.wilson@canterbury.ac.nz)
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Questionnaire

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

A large disaster has occurred, such as the "Big One", an earthquake shattering the peace of the Southern Alps, or a large tsunami.

You may be at home; you may be at work; you could be anywhere!

This 15 minute confidential questionnaire is about you, your household, and your community, your preparations against the affects of a large-scale disaster, and the measure of your ability to cope with events. You will be asked about your household, your weekly routines, your intentions in case of evacuation, the house you live in, and provisions at your disposal.

The outcome will concentrate on the local resident population and visitors; where people are at different time of the day and week, and their movements.

Water poured into the dry dock at Lyttelton, in the South Island, during several of the surges from the Chile tsunami in May 1960.

Although the questionnaire should be filled in by one person, in the centrepiece you are asked to also provide information on as many as three other consenting, representative people in your household, in order to gain an insight into the dynamics of your household during a typical week. This information is important to help us understand where members of your household could be at the time of the onset of a disaster and their intention to travel during the first three days.

Thank you for your contribution.

Confidentiality

This questionnaire is confidential. This questionnaire has been GPS tagged, yet any personal information contained within the answers will not be traceable in the final published thesis, nor in any prior or subsequent papers, reports, or PhD thesis. A thesis is a public document accessible via the University of Canterbury library database. By completing this questionnaire, the respondent acknowledges this and allows the answers to be used in this and any associated research under the same confidentiality terms by which it was originally obtained. As this questionnaire is anonymous, it will not be possible to withdraw your contribution after it has been submitted as it will not be identifiable – it is deemed you will have implicitly consented to this by submitting your reply. If you wish to receive a copy of the research results, please contact the Principal Researcher or Supervisor, named below.

Principal researcher: Julian Idle (julian.idle@pg.canterbury.ac.nz)
Supervisor: Dr. Thomas Wilson (thomas.wilson@canterbury.ac.nz)
http://www.nhrc.canterbury.ac.nz/
Phone: (+64-3) 364-2987 ext 45511
Fax: +64 3 364 2769

Natural Hazards Research Centre
Department of Geological Sciences
University of Canterbury
Private Bag 4800
Christchurch

About You

Occupation:

Your Household

Please describe your household. This will enable a better understanding of the needs of the residents during an emergency.

How many persons of what age group and gender live in your household on a permanent basis?

Please write the number in the appropriate boxes, below

	Male	Female	Total
Under 5 Years Of Age			
5 – 10 Years Of Age			
11 – 16 Years Of Age			
17 – 19 Years Of Age			
20 – 49 Years Of Age			
50 – 64 Years Of Age			
65 – 79 Years Of Age			
80 Years Of Age and Above			
Total			

What is your combined, annual household income, from all sources?

Please tick the appropriate box

- Less than $20,000
- $20,000 to $39,999
- $40,000 to $59,999
- $60,000 to $79,999
- $80,000 to $99,999
- $100,000 to $149,999
- $150,000 or more
- Prefer not to answer

What is the predominant ethnic mix of your household?

Please tick the appropriate box(es)

- European (pakeha)
- New Zealand Maori
- Pacific Island Polynesian
- South-East Asian
- Southern Asian
- Prefer not to answer
- Other (please specify)

Does anyone in your household suffer from an acute medical condition requiring the following treatment?

Please tick the appropriate box(es)

- Critical medication
- Life support machinery
- Constant supervision
- Frequent visits from or to doctor

Does this require an uninterrupted electrical power supply? Yes No Don't know

Does this require a clean/pressurised water supply? Yes No Don't know

Would you consider your household to include one or more persons that are frail or who would require assistance during an emergency, but are otherwise medically sound? Yes No Don't know

What is assistance would be required?

Do you have animals in your care?

Please tick the appropriate box(es)

- Small pets (cats, dogs, fish)
- Livestock (horses, goats, etc)
- Other (please specify)

Are they able to fend for themselves during a disaster? Yes No Don't know

Are you able to feed and water them during a disaster? Yes No Don't know

Are you able to transport them to a safe area, if needed? Yes No Don't know

Do you have enough transport/cages for them all at one time? Yes No Don't know

If the emergency services asked you to evacuate but you could not take any animals with you, would you:

- evacuate, after making preparations (food, water, shelter) for the animals to stay behind?
- evacuate, with the expectation the emergency services will care for you animals?
- have at least one person stay behind, in order to look after the animals?

Is any member of your household involved in community, volunteer, or emergency services?

Please tick the appropriate box(es)

- Police
- St John Ambulance
- Medical (Doctor, Hospital)
- Salvation Army
- Community Watch
- Pharmacy
- Electricity Supply
- Civil Defence
- Fire Brigade
- Lifeboat
- Red Cross
- Local Church
- Elderly Care Provider
- RSPCA
- Telecommunications
- Christchurch City Council
- Other (please specify)

Household Preparation and Planning

*This section addresses your household's preparations in readiness for a large disaster. Your answers will help gauge how much outside help is expected to be received by those affected, and if the community can help themselves, or self-evacuate. The answers should concern the first **three days** after the disaster has struck.*

If your house was still structurally sound yet critical services (water, power, telephone) were disrupted, would you consider self-evacuating at least one member of your household to somewhere outside of the affected area within the first three days? Yes ☐ No ☐ Don't know ☐

If your house suffered structural failure (collapsed roof or walls, etc) within the first three days would members of your household:

Please tick as many as appropriate

- self-evacuate to somewhere outside of the area ☐
- expect to be evacuated by friends or family ☐
- expect to be evacuated by the emergency services ☐
- stay put and expect to be supported by the emergency services ☐
- stay put and expect to live independently ☐

Other (please specify) _____

In case of an emergency, would you need to collect children from school or day care centre? Yes ☐ No ☐ Don't know ☐

Please provide name(s) of school(s) or day care centre(s)

_____

In case of an emergency, does you household have a planned meeting place (whether at home or elsewhere)? Yes ☐ No ☐ Don't know ☐

Please provide name of town/city/suburb

_____

If you were away from your home when a large disaster struck, such as an earthquake or tsunami, would you try to get home? Yes ☐ No ☐ Don't know ☐

If you were to be evacuated, do you have somewhere to go to (friends or family) outside of the affected area?

Please provide name of town/city/suburb

_____

Do you use your home as a Homestay or Bed & Breakfast? Yes ☐ No ☐

How many guests can you accommodate? _____

Do you have an emergency plan for your guests? Yes ☐ No ☐ Don't know ☐

Do you have any arrangements for shelter with your neighbours or community group members?

Please tick as many as appropriate

- We do not know our neighbours ☐
- We would shelter our neighbours if asked ☐
- We know our neighbours but have no arrangement ☐
- We have an arrangement with our neighbours ☐

- We do not belong to any community groups ☐
- We would receive help from our community group ☐
- We would shelter other community group members ☐

Name of community group (church, club, association, etc), if appropriate?

_____

Have you or anyone else in your household experienced a large-scale or devastating natural disaster?

Please tick as many as appropriate and provide some context (where/when)

Earthquake	☐	
Tsunami	☐	
Wild fire	☐	
Tornado/Hurricane	☐	
Heavy snows/blizzard	☐	
Landslide	☐	
Flood	☐	
Volcanic eruption	☐	

Thinking back to the recent tsunami caused by the Chilean earthquake in February 2010, what was your reaction?

Please tick as many as appropriate

- Didn't know it was happening ☐
- Found out too late to evacuate, so stayed at home ☐
- Stayed at home because house was high enough to not worry ☐
- Self-evacuated to higher ground ☐
- Went to the harbour to look out for the wave ☐
- Went up to Summit Road to watch ☐
- Went about normal business ☐
- Did not live in the area at the time ☐
- Other ☐

_____

The answers in the following double-spread will be used to analyse the movements of representative household members at different times of the day and days of the week. It will be used to calculate how many people would be inside or outside of the study area and, based on their expected movements after a disaster, to calculate where traffic management resources should be deployed to coordinate emergency services and private traffic in and around Lyttelton-Rapaki. Please obtain the consent of those whose movements are being described before filling out this page, or let those household members fill out their section themselves.

Role in the household

Main decision maker ☐
Shared decision maker ☐
Other person, 16 Years Of Age or older ☐
Other person, Less Than 16 Years Of Age ☐

Location of work/school (suburb)

Weekly Schedule?

Please insert the letters into the schedule, below:

H – Home, W – Work, E – Education,

S – Shopping, R - Recreation

	M	Tu	W	Th	F	Sa	Su
Midnight – 6am							
6am – 9am							
9am – 12pm							
12pm – 3pm							
3pm – 6pm							
6pm – 9pm							
9pm - midnight							

When leaving Lyttelton, do you *usually* pass:

Rapaki ☐ The Tunnel ☐ Evan's Pass ☐

Primary form of transport

Private car ☐ Bus ☐ Bicycle ☐
Shared car ☐ Taxi ☐ On foot ☐

Do you own or use a vehicle? Yes ☐ No ☐

What is its registration? ☐☐☐☐☐☐

Where is it normally parked?

In garage ☐ On your property ☐
On road ☐ Other ☐

Role in the household

Main decision maker ☐
Shared decision maker ☐
Other person, 16 Years Of Age or older ☐
Other person, Less Than 16 Years Of Age ☐

Location of work/school (suburb)

Weekly Schedule?

Please insert the letters into the schedule, below:

H – Home, W – Work, E – Education,

S – Shopping, R - Recreation

	M	Tu	W	Th	F	Sa	Su
Midnight – 6am							
6am – 9am							
9am – 12pm							
12pm – 3pm							
3pm – 6pm							
6pm – 9pm							
9pm - midnight							

When leaving Lyttelton, do you *usually* pass:

Rapaki ☐ The Tunnel ☐ Evan's Pass ☐

Primary form of transport

Private car ☐ Bus ☐ Bicycle ☐
Shared car ☐ Taxi ☐ On foot ☐

Do you own or use a vehicle? Yes ☐ No ☐

What is its registration? ☐☐☐☐☐☐

Where is it normally parked?

In garage ☐ On your property ☐
On road ☐ Other ☐

Role in the household

Main decision maker ☐
Shared decision maker ☐
Other person, 16 Years Of Age or older ☐
Other person, Less Than 16 Years Of Age ☐

Location of work/school (suburb)

Weekly Schedule?

Please insert the letters into the schedule, below:

H – Home, W – Work, E – Education,

S – Shopping, R - Recreation

	M	Tu	W	Th	F	Sa	Su
Midnight – 6am							
6am – 9am							
9am – 12pm							
12pm – 3pm							
3pm – 6pm							
6pm – 9pm							
9pm - midnight							

When leaving Lyttelton, do you *usually* pass:

Rapaki ☐ The Tunnel ☐ Evan's Pass ☐

Primary form of transport

Private car ☐ Bus ☐ Bicycle ☐
Shared car ☐ Taxi ☐ On foot ☐

Do you own or use a vehicle? Yes ☐ No ☐

What is its registration? ☐☐☐☐☐☐

Where is it normally parked?

In garage ☐ On your property ☐
On road ☐ Other ☐

Role in the household

Main decision maker ☐
Shared decision maker ☐
Other person, 16 Years Of Age or older ☐
Other person, Less Than 16 Years Of Age ☐

Location of work/school (suburb)

Weekly Schedule?

Please insert the letters into the schedule, below:

H – Home, W – Work, E – Education,

S – Shopping, R - Recreation

	M	Tu	W	Th	F	Sa	Su
Midnight – 6am							
6am – 9am							
9am – 12pm							
12pm – 3pm							
3pm – 6pm							
6pm – 9pm							
9pm - midnight							

When leaving Lyttelton, do you *usually* pass:

Rapaki ☐ The Tunnel ☐ Evan's Pass ☐

Primary form of transport

Private car ☐ Bus ☐ Bicycle ☐
Shared car ☐ Taxi ☐ On foot ☐

Do you own or use a vehicle? Yes ☐ No ☐

What is its registration? ☐☐☐☐☐☐

Where is it normally parked?

In garage ☐ On your property ☐
On road ☐ Other ☐

Your Property

The answer you provide will enable a clearer understanding of how fast repairs will be made to your home.

Nature of Occupancy *Please tick one*

- ☐ Owned With Mortgage
- ☐ Owned Without Mortgage
- ☐ Rented or Leased from Private Person/Company
- ☐ Rented or Leased from Housing Corporation
- ☐ Rented or Leased from Other Government Department
- ☐ Rented or Leased from Local Authority
- ☐ Rented or Leased Landlord Not Specified
- ☐ Provided Free
- ☐ Prefer not to answer

Insurance

The answers you provide here will help to assess how long it might take you to recover your material losses after a natural disaster.

Do you have household contents insurance cover against losses caused by natural disaster? ☐ Yes ☐ No ☐ Don't know ☐ Prefer not to answer

How much insurance cover do you have? $

Who is your main insurer?

Do you have additional building insurance cover against losses caused by natural disaster? ☐ Yes ☐ No ☐ Don't know ☐ Prefer not to answer

How much insurance cover do you have? $

Who is your main insurer?

The Ground You Live On

The answers you provide will help to assess any issues relating to ground stability that may affect your property or that of neighbouring property, including roads and infrastructure.

Are you aware of any problems your home may be facing relating to ground stability? *Please tick as many as appropriate*

Soil erosion	☐	Movement of building	☐
Cracks in soil when dry	☐	Shaking due to normal traffic	☐
Damp soil that doesn't dry out	☐	Damp foundations	☐
Cracks in retaining walls	☐	Historical or recent slips	☐

Do you have any concerns about the ground in the neighbourhood area you live in? ☐ Yes ☐ No ☐ Don't know

Age and State of Dwelling

The answers you provide will help to assess how long it might take for emergency services to attend to you, or to assess how easy it would be for you to evacuate. It is not just your building but also those of your neighbours' that might be a risk to your safety, especially if they cause obstruction, catch fire, or otherwise occupy emergency personnel.

Please tick one

Less Than Five Years Old	☐	50 – 74 Years Old	☐
5 – 14 Years Old	☐	75 – 100 Years Old	☐
15- 24 Years Old	☐	More Than 100 Years Old	☐
25 – 49 Years Old	☐		

State of Maintenance *Please tick one*

Well-maintained	☐	Adequate	☐
Good	☐	Poor (leaks and breezes)	☐
Comfortable	☐	Being renovated	☐

Living Space Heating *Please tick as many as are applicable*

Electric Oil Heater	☐	Electric Panel (storage) heater	☐
Electric AC	☐	Gas	☐
Wood burner	☐	Pellet burner	☐

Water Heating *Please tick as many as are applicable*

Electric	☐	Solar	☐
Gas	☐	Wet back	☐

Structure

Main Structure *Please tick one*

- Timber Frame ☐
- Joisted Masonry ☐
- Structural Steel frame ☐
- Concrete Block ☐
- Reinforced Concrete ☐
- Stone ☐
- Other (please specify) ☐

Main Foundations *Please tick one*

- Rammed earth, etc ☐
- Basement ☐
- Slab on Grade ☐
- Pier and Beam ☐
- Pile and Beam ☐
- Other (please specify) ☐

Number of storeys: ☐

Structural Details

Please tick as many as are appropriate

					Please circle
Window Glazing	Single ☐	Double ☐			
Chimney(s)	Brick ☐	Metal ☐			
Deck	On ground ☐	Elevated ☐			
Garage	Integrated ☐	Free standing ☐	Bays:	1 2 2+	
Parking hard-stand	On ground ☐	Elevated ☐	Bays:	1 2 2+	

Independent Energy and Water Supply

Please tick boxes appropriately and provide the total capacity

- Water Tank(s) ☐ Auto Shut-off valve ☐ Total Capacity (l)
- Gas Tanks(s) ☐ Auto Shut-off valve ☐ Total Capacity (l)
- Electrical Gen Set ☐ Auto Start ☐ Power (kW)
  - Portable ☐ Fixed ☐
  - Fuel: Petrol ☐ Diesel ☐ Tank Capacity (l)
  - Running time (hr)
- Required for special needs: ☐

Provisions

According to www.getthru.govt.nz, you are expected to have enough food, water, clothing, a medical kit, a radio, and a light for use in the first three days following an emergency.

Do you have an emergency provisions/getaway kit? Yes ☐ No ☐ Don't know ☐

Inventory close at hand

Would you be able to assemble an emergency getaway kit for your household given your current household inventory? The following table provides a selection of items suggested by the Civil Defence.

(tick all that apply)

Bottled drinking water (3 litres per person per day)	☐	Non-perishable food (canned or dried)	☐
Water for washing and cooking	☐	Can opener, eating utensils	☐
Waterproof torch and spare batteries	☐	Portable cooking stove (Primus or gas BBQ)	☐
First aid kit and essential medicines	☐	AM/FM radio and spare batteries	☐
Face and dust masks	☐	Toilet paper and large rubbish bags for disposal	☐
Blankets or sleeping bags	☐	Pet supplies	☐
Strong outdoor shoes	☐	Wind and rain proof clothing	☐
Birth and Marriage certificates	☐	Sun hats and sunscreen	☐
Insurance policies	☐	Drivers' Licences and Passports	☐
Towels, soap, toothbrush and sanitary items	☐	Family photos	☐
Knife, scissors, etc	☐	A change of clothes	☐
Duffelbag, Rucksack, etc	☐	Toys, baby care, nappies, etc	☐

Do you have enough provisions for your household for the first three days after a disaster strikes? Yes ☐ No ☐ Don't know ☐

From where would you think of purchasing or procuring more provisions during an emergency?

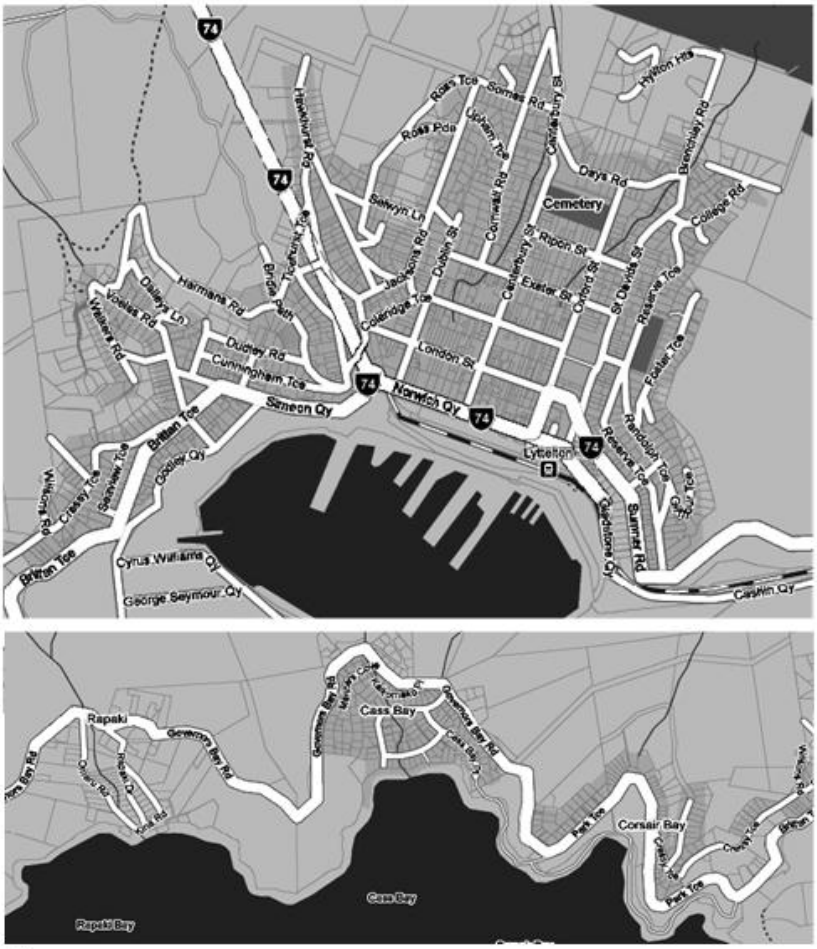
(tick all that apply)

Local supermarket	☐	City supermarket	☐	Petrol Station	☐
Dairy	☐	Restaurant	☐	Hotel	☐
Neighbour	☐	Civil Defence Post	☐	Salvation Army, etc	☐
Other (please specify)	☐				

After answering the questions on this page, would you now consider buying more provisions for your household? Yes ☐ No ☐ Don't know ☐

Evacuation

Finally, even if you haven't planned to evacuate, would you please use a pen or soft pencil to draw a line showing your preferred route from your home to refuge outside of the immediate Rapaki-Lyttelton area. This will help to distinguish potential areas of congestion.



Thank you!

Your help in answering these questions is greatly appreciated. Please return the completed questionnaire using the stamped, pre-addressed envelope provided. If you would like to share any further comments about emergency preparedness, or this questionnaire, please use the area below.

C. Pre-September 2010 Interview

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Natural Hazards Research Centre

Department of Geological Sciences

INFORMATION

You are invited to participate as a subject in a research project investigating the role of population movement in hazard management, preparedness, and mitigation, in the study area between Lyttelton and Rapaki.

Your involvement in this project will be to answer an oral six-question survey. You will be invited to also complete a 15-minute questionnaire.

The project is being carried out as a requirement for the Degree of Master of Science, Hazard and Disaster Management, by Julian Idle, under the supervision of Dr. Thomas Wilson, who can be contacted at 03 364 2987 Ext 45511, and Associate Professor Tim Davies, who can be contacted at 03 364 2987 Ext 7502. They will be pleased to discuss any concerns you may have about participation in the project.

By answering the survey questions or completing the questionnaire it will be understood that you have consented to contribute to the study, and that you consent to publication of the results of the project with the understanding that anonymity will be preserved.

The results of the project will be published as part of a thesis, a public document accessible via the University of Canterbury library database, but you may be assured of the complete confidentiality of data gathered in this investigation. To ensure anonymity and confidentiality, the returned completed questionnaire will only be handled by the principal researcher. The questionnaires will be identified by a unique number. All material will be handled and stored in a secure environment.

If you have agreed to complete the questionnaire, please return the completed questionnaire by 30th September 2010, using the postage-paid, self-addressed envelope provided.

The project has been reviewed ***and approved*** by the University of Canterbury Human Ethics Committee.

Principal researcher: Julian Idle (julian.idle@pg.canterbury.ac.nz)
Supervisor: Dr. Thomas Wilson (thomas.wilson@canterbury.ac.nz)
http://www.nhrc.canterbury.ac.nz/
Phone: (+64-3) 364-2987 ext 45511
Fax: +64 3 364 2769

Natural Hazards Research Centre
Department of Geological Sciences
University of Canterbury
Private Bag 4800
Christchurch

If your house was still structurally sound yet critical services (water, power, telephone) were disrupted, would you consider self-evacuating at least one member of your household to somewhere outside of the affected area within the first three days?

Yes/No/Don't know

If your house suffered structural failure (collapsed walls or roof, etc) within the first three days would members of your household:

self-evacuate to somewhere outside of the area
expect to be evacuated by friends or family
expect to be evacuated by the emergency services
stay put and expect to be supported by the emergency services
stay put and expect to live independently
Other (please specify)

In case of an emergency, would you need to collect children from school or day care centre?

Yes/No/Don't know
Please provide name(s) of school(s) or day care centre(s)

In case of an emergency, does you household have a planned meeting place (whether at home or elsewhere)?

Yes/No/Don't know
Please provide name of town/city/suburb

If you were away from your home when a large disaster struck, such as an earthquake or tsunami, would you try to get home?

Yes/No/Don't know

If you were to be evacuated, do you have somewhere to go to (friends or family) outside of the affected area?

Yes/No/Don't know
Please provide name of town/city/suburb

D. Post-June 2011 Survey

Disaster Response and Preparedness in Lyttelton

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Supported with funding from
CANTERBURY Civil Defence Emergency Management Group

You are invited to participate in a study investigating the preparedness and disaster response of the Lyttelton community following the 22nd February and 13th June earthquakes.

We would greatly appreciate your involvement in this study. If you would like to participate, please complete this 20-minute questionnaire.

You will need to think of your household's current situation and actions in the 7 days immediately following the 22nd February and 13th June earthquakes.

We are very aware that this period has been traumatic for many and that you may not wish to revisit those memories. As such, there is no obligation to respond to this confidential questionnaire. However, we would be most grateful for any contribution.

While this is not a social science project but a disaster response and preparedness survey, it is understood that having an injured or deceased household member may affect the other household members' action and travel plans.

All households in Lyttelton are receiving this questionnaire. After completing the questionnaire please return it to us in the envelope provided by **19th August 2011.** We need responses from as many different households as possible, so we would really value your response.

In your household, the person who should complete this questionnaire is **an adult (age 18 or older) involved with household decision making.**

All replies will be confidential and we will only report on general trends.

If you wish to add any comments you may have of a general nature, please do so on the separate sheet of paper, included.

The project has been reviewed ***and approved*** by the University of Canterbury Human Ethics Committee.

This questionnaire is also available to complete online by following the link at
http://www.nhrc.canterbury.ac.nz/julian_idle.shtml

Confidentiality

This questionnaire is confidential. The number printed at the top is the Internet survey number used to identify duplicate responses. Any personal information contained within the answers will not be traceable in the final published report, neither in any prior or subsequent papers, reports, or thesis. **By completing the questionnaire it will be understood that you have consented to contribute to the study, and that you consent to publication of the results of the project with the understanding that anonymity will be preserved in all publications.** The respondent further consents to their answers being used in any associated research (including that conducted by the Ministry of Civil Defence and Emergency Management and GNS Science) under the same confidentiality terms by which it was originally obtained. The results of the project will be published as part of a thesis, a public document accessible via the University of Canterbury library database. If you wish to receive a copy of the research results, please contact the Principal Researcher or Supervisor, named below. Findings from the study will be used to inform the local civil defence community to help improve advice and support for future extreme events.

Principal researcher: Julian Idle (julian.idle@pg.canterbury.ac.nz)
Supervisor: Dr. Thomas Wilson (thomas.wilson@canterbury.ac.nz)

Phone: (03) 364-2987 ext 45511
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New Zealand

Disaster Response and Preparedness in Lyttelton

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Supported with funding from
CANTERBURY Civil Defence Emergency Management Group

You are invited to participate in a study investigating the preparedness and disaster response of the Lyttelton community following the 22nd February and 13th June earthquakes.

We would greatly appreciate your involvement in this study, especially as we understand you have moved away from the area. The enclosed questionnaire should take about 20 minutes to complete.

You will need to think of your household's current situation and actions in the 7 days immediately following the 22nd February and 13th June earthquakes.

We are very aware that this period has been traumatic for many and that you may not wish to revisit those memories. As such, there is no obligation to respond to this confidential questionnaire. However, we would be most grateful for any contribution.

While this is not a social science project but a disaster response and preparedness survey, it is understood that having an injured or deceased household member may affect the other household members' action and travel plans.

All households in Lyttelton have already received this questionnaire. We understand that you may have moved away from the area and so would not have received the hand-delivered questionnaire. After completing the questionnaire please return it to us in the envelope provided by **31st August 2011.** We need responses from as many different households as possible, especially those that have left the Lyttelton area, so we would greatly value your response.

In your household, the person who should complete this questionnaire is **an adult (age 18 or older) involved with household decision making.**

All replies will be confidential and we will only report on general trends.

The project has been reviewed ***and approved*** by the University of Canterbury Human Ethics Committee.

This questionnaire is also available to complete online by following the link at
http://www.nhrc.canterbury.ac.nz/julian_idle.shtml

Confidentiality

This questionnaire is confidential. The number printed at the top is the Internet survey number used to identify duplicate responses. Any personal information contained within the answers will not be traceable in the final published report, neither in any prior or subsequent papers, reports, or thesis. **By completing the questionnaire it will be understood that you have consented to contribute to the study, and that you consent to publication of the results of the project with the understanding that anonymity will be preserved in all publications.** The respondent further consents to their answers being used in any associated research (including that conducted by the Ministry of Civil Defence and Emergency Management and GNS Science) under the same confidentiality terms by which it was originally obtained. The results of the project will be published as part of a thesis, a public document accessible via the University of Canterbury library database. If you wish to receive a copy of the research results, please contact the Principal Researcher or Supervisor, named below. Findings from the study will be used to inform the local civil defence community to help improve advice and support for future extreme events.

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ESSENTIAL CONTACTS

Earthquake Government Helpline: 0800 779 997

A service for people requiring information on income support, housing options, health issues, community assistance, Civil Defence or any other government service.

Healthline (24 hours): 0800 611 116

The service is staffed by registered nurses who will assess your health needs, and give information and advice to help you decide on the best level of care.

Earthquake Commission (EQC): 0800 DAMAGE (0800 326 243)

For information on EQC's insurance cover, cleaning up and making a claim.

Canterbury Earthquake Recovery Authority (CERA): 0800 RING CERA (0800 7464 2372)

Set up by the Government to lead recovery work following the devastating earthquakes of September 2010 and February 2011.

Christchurch City Council customer services: 03 941 8999

For assessment of major structural damage to your home or business premises or for help with essential council services such as water supply or sewage disposal.

WELLBEING SUPPORT SERVICES

Emergency accommodation, counselling services, income support, health safety and employment relations

- Earthquake and Emergency Assistance
  (http://www.msd.govt.nz/emergency/index.html)
  The Ministry of Social Development's main web page for helping those affected by the earthquake. It includes where to go if you need urgent emergency assistance. Includes links to information about welfare centres, and the status of the Ministry's offices in Christchurch.
- Work and Income's Canterbury earthquake support page
  (http://www.workandincome.govt.nz/about-work-and-income/news/canterbury-earthquake/index.html)
  Includes links to information about financial assistance you and your family may qualify for and information about the earthquake income support subsidy.
- Housing Emergency Lease Programme (HELP)
  If you are a property owner interested in offering accommodation, or a Canterbury resident needing temporary accommodation please go to www.housinghelp.govt.nz or call **0800 HELP 00 (435 700).**
- Health, safety and employment relations
  (http://www.dol.govt.nz/quake2010)
  Information designed to get http://www.dol.govt.nz/quake2010
- Ministry of Health quake counselling and support services
  (http://www.moh.govt.nz/moh.nsf/indexmh/coping-with-stress-factsheets)
- Traumatic incident advice from the Ministry of Education
  (http://www.minedu.govt.nz)
  Traumatic incident information and advice for schools following the Canterbury earthquake, share these tips with parents, whānau and your school community.
- Helping adolescents and coping personally
  (http://disasters.massey.ac.nz/index.htm)
  Support fact sheets developed by Massey University are available for download in either PDF or MS Word format.

(Contact information taken from http://www.canterburyearthquake.govt.nz)

Disaster Response and Preparedness in Lyttelton

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Supported with funding from CANTERBURY Civil Defence Emergency Management Group

You are invited to participate in a study investigating the preparedness and disaster response of the Lyttelton community following the 22nd February and 13th June earthquakes.

We would greatly appreciate your involvement in this study. If you would like to participate, please complete this 20-minute questionnaire.

You will need to think of your household's current situation and actions in the 7 days immediately following the 22nd February and 13th June earthquakes.

Internet survey number:

All households in Lyttelton are receiving this questionnaire. After completing the questionnaire please return it to us in the envelope provided by **19th August 2011**. We need responses from as many different households as possible, so we would really value your response.

This survey is supported by the Canterbury Civil Defence and Emergency Management Group. Responses will be used to help inform future disaster planning and response.

In your household, the person who should complete this questionnaire is **an adult (age 18 or older) involved with household decision making.**

The project has been reviewed ***and approved*** by the University of Canterbury Human Ethics Committee.

This questionnaire is also available to complete online by following the link at
http://www.nhrc.canterbury.ac.nz/julian_idle.shtml

1 When did your household move to your current address?

Month M M / Year Y Y

2 How many persons live in your household on a permanent basis?

Please print the number in the appropriate boxes, below

	Male	Female	Total
Under 5 years of age			
5 – 14 years of age			
15 – 19 years of age			
20 – 49 years of age			
50 – 64 years of age			
65 – 79 years of age			
80 years of age or over			
Total			

3 How many motor vehicles (not counting motorbikes) do people in your household have available for their use?

- none
- 1
- 2
- Or more (print number of motor vehicles)

4 Where were you living when the February earthquake event occurred (Tuesday, 22nd February 2011)?

- At my current address
- Elsewhere – print name of town/city/suburb
- Unable to recall

5 Did you personally experience the February earthquake or any aftershocks in the seven days following the event?

- Yes
- No

6 Where were you living when the June earthquake events occurred (Monday, 13th June 2011)?

- At my current address
- Elsewhere – print name of town/city/suburb
- Unable to recall

7 Did you personally experience the June earthquakes or any aftershocks in the seven days following the event?

- Yes
- No

8 Did you have a *personal* emergency provision kit (snack, drink bottle, small first aid kit, torch, radio, cell phone) with you during the earthquakes?

	February	June
Yes		
No		

9 Do you now have a *personal* emergency provisions kit with or close to you at all times (at home, in the office, in the car)?

Tick all that apply

- Yes, at home
- Yes, at office
- Yes, in the car
- No

10 Did you use a *household* emergency provisions/getaway kit in the *seven* days following the earthquakes?

	February	June
Yes		
No – had one, but didn't use it		
No – didn't have one		
Unable to recall		

11 Did your household have enough emergency provisions for the first *three* (3) days following the earthquakes?

	February	June
Yes		
No		
Unable to recall		

12 Did your household have enough emergency provisions for the first *seven* (7) days following the earthquakes?

	February	June
Yes		
No		
Unable to recall		

13 During the seven days after the earthquakes, where did the household get extra provisions from?

	Tick all that apply: February	Tick all that apply: June
Local supermarket		
Petrol station		
Restaurant		
Neighbour		
City Mission		
Salvation Army		
Unable to recall		
City supermarket		
Dairy		
Hotel/motel		
Civil Defence Post/Shelter		
Defence Force/Navy		
Red Cross		
Did not require any		

14 *Since* the February earthquake and up until now, has your household specifically purchased further provisions and equipment suitable for emergency situations?

- Yes
- No

15 What inventory does your household have at hand, now, specifically for emergencies, i.e. you don't need to go out of the way to retrieve, collect or purchase?

	Tick all that apply		Tick all that apply
A supply of drinking water other than from the tap (3 litres per person daily)		Non-perishable food (canned or dried rations)	
Water for washing and cooking		Hand-operated can opener, eating utensils	
Waterproof torch and spare batteries		Portable cooking stove or gas BBQ	
First aid kit and essential medicines		AM/FM radio and spare batteries	
Face and dust masks		Toilet paper and large rubbish bags for disposal	
Blankets or sleeping bags		Pet supplies	
Strong outdoor shoes		Wind and rain-proof clothing	
Towels, soap, toothbrush and sanitary items		Sun hats and sunscreen	
Sharp (utility) knife, scissors, etc		A change of clothes	
Duffel bag, backpack, holdall, suitcase, etc		Toys, baby care, nappies, etc	
Cash		Tent or other portable shelter	
Insurance policies		Drivers licenses and Passports	
Birth and Marriage certificates		Family photos (for identification)	

16 Please provide the structural or critical service failures that affected your household caused by the earthquakes

	Tick all that apply: February	Tick all that apply: June		Tick all that apply: February	Tick all that apply: June
Roof			Water tank(s)		
Chimney			Water supply		
External wall façade/facia			Waste water		
Foundations/piles			Telephone/Internet		
External wall - structural			Electrical wiring - internal		
Windows/Doors			Electricity supply		
Internal wall			Deck/Garage/Sleep-out		
Ceiling			Retaining wall		
Floor			Path/driveway		
Unable to recall			None		
Print other failure(s):					

17 Starting with yourself as Person 1, please answer where each person in your household was at the time of the February earthquake. Please do not enter anything into superfluous columns if there are less than 6 people in your household.

	Person 1	Person 2	Person 3	Person 4	Person 5	Person 6
	Tick one	Tick one	Tick one	Tick one	Tick one	Tick one
At home	☐	☐	☐	☐	☐	☐
Elsewhere - indoors	☐	☐	☐	☐	☐	☐
Elsewhere - outdoors	☐	☐	☐	☐	☐	☐
Travelling in car, bus, etc	☐	☐	☐	☐	☐	☐
Print location (suburb, town, etc)						
Unable to recall	☐	☐	☐	☐	☐	☐

18 Using the same order as above, please answer which location(s) (if any) each person in your household travelled to immediately after the February earthquake, *before* all members of the household were assembled or accounted for. Please give the reason for going to each location. * *While this is not a social science project but a disaster response and preparedness survey, it is understood that having an injured or deceased household member may affect the other household members' action and travel plans*

	Person 1	Person 2	Person 3	Person 4	Person 5	Person 6
Print 1st location (suburb, town, etc)						
Reason						
Print 2nd location (suburb, town, etc)						
Reason						
Print 3rd location (suburb, town, etc)						
Reason						

19 Using the same order as above, please enter the mode(s) of transport used (even if only for a short distance) and how long it took in total to reach the household designated meeting place, or home, after the February earthquake. (Tick all that apply)

	Person 1	Person 2	Person 3	Person 4	Person 5	Person 6
Drove home in vehicle	☐	☐	☐	☐	☐	☐
Rode as passenger with household member / neighbour / friend	☐	☐	☐	☐	☐	☐
Rode as passenger with a stranger	☐	☐	☐	☐	☐	☐
Took a taxi	☐	☐	☐	☐	☐	☐
Rode the bus	☐	☐	☐	☐	☐	☐
Bicycle	☐	☐	☐	☐	☐	☐
On foot	☐	☐	☐	☐	☐	☐
Please fill in the total journey time for each person	hours	hours	hours	hours	hours	hours

20 Using the same order as above, please enter how long it took after the February earthquake until each person made contact with the household or was otherwise accounted for.

	Person 1	Person 2	Person 3	Person 4	Person 5	Person 6
How long before each person made contact	hours	hours	hours	hours	hours	hours

21 Using the same order as on the last page, please answer which location(s) (if any) each person in your household travelled to in the first 24 hours *after* returning home after the February earthquake. Please give the reason for going to each location. * *While this is not a social science project but a disaster response and preparedness survey, it is understood that having an injured or deceased household member may affect the other household members' action and travel plans*

	Person 1	Person 2	Person 3	Person 4	Person 5	Person 6
Print 1st location (suburb, town, etc)						
Reason						
Print 2nd location (suburb, town, etc)						
Reason						
Print 3rd location (suburb, town, etc)						
Reason						

22 Using the same order as above, please answer which location(s) (if any) each person in your household evacuated to within seven days of the February earthquake. Please give their reasons for leaving, the date they left, and how long for. Or, if they stayed at home, please tick the box for the circumstances which best apply.

	Person 1	Person 2	Person 3	Person 4	Person 5	Person 6
	Tick one	Tick one	Tick one	Tick one	Tick one	Tick one
Evacuated...						
by self	☐	☐	☐	☐	☐	☐
by friend/family	☐	☐	☐	☐	☐	☐
by emergency services	☐	☐	☐	☐	☐	☐
Evacuated to where(suburb, town, etc):						
Reason for leaving?						
Date left dwelling (22 – 29)?						
Stayed away for how many days?						
Stayed at home because...						
wanted to (own choice)	☐	☐	☐	☐	☐	☐
needed to (dependents)	☐	☐	☐	☐	☐	☐
had to (no place to go)	☐	☐	☐	☐	☐	☐

23 Did you have dependents in your care at the time of the February earthquake that required medical attention?

No ☐ go to **25**

Yes ☐

24 Was medical attention available?

Yes – immediately ☐

Yes – within 24 hours ☐

Yes – within three days ☐

No ☐

Unable to recall ☐

25 Did you have animals in your care at the time of the February earthquake?

No ☐ go to **27**

Yes - small pets (cat, dog, fish, etc) ☐

Yes - livestock (horses, goats, etc) ☐

26 Were you able to tend to your animals during the seven day period following the February earthquake?

Yes ☐

No ☐

Unable to recall ☐

27 Using the same order as on the last page, please answer where each person in your household was at the time of the 13th June earthquakes (13:00 and 14:20).

	Person 1		Person 2		Person 3		Person 4		Person 5		Person 6	
	13:00	14:20	13:00	14:20	13:00	14:20	13:00	14:20	13:00	14:20	13:00	14:20
At home	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Elsewhere - indoors	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Elsewhere - outdoors	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Travelling in car, bus, etc	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Print **13:00** location (suburb, town, etc)												
Print **14:20** location (suburb, town, etc)												
Unable to recall	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

28 Using the same order as above, please answer which location(s) (if any) each person in your household travelled to immediately after the June earthquakes, *before* all members of the household were assembled or accounted for. Please give the reason for going to each location. * *While this is not a social science project but a disaster response and preparedness survey, it is understood that having an injured or deceased household member may affect the other household members' action and travel plans*

	Person 1	Person 2	Person 3	Person 4	Person 5	Person 6
Print 1st location (suburb, town, etc)						
Reason						
Print 2nd location (suburb, town, etc)						
Reason						
Print 3rd location (suburb, town, etc)						
Reason						

29 Using the same order as above, please enter the mode(s) of transport used (even if only for a short distance) and how long it took in total to reach the household designated meeting place, or home, on 13th June. (Tick all that apply)

	Person 1	Person 2	Person 3	Person 4	Person 5	Person 6
Drove home in vehicle	☐	☐	☐	☐	☐	☐
Rode as passenger with household member / neighbour / friend	☐	☐	☐	☐	☐	☐
Rode as passenger with a stranger	☐	☐	☐	☐	☐	☐
Took a taxi	☐	☐	☐	☐	☐	☐
Rode the bus	☐	☐	☐	☐	☐	☐
Bicycle	☐	☐	☐	☐	☐	☐
On foot	☐	☐	☐	☐	☐	☐
Please fill in the total journey time for each person	hours	hours	hours	hours	hours	hours

30 Using the same order as above, please enter how long it took after the June earthquakes until each person made contact with the household or was otherwise accounted for.

	Person 1	Person 2	Person 3	Person 4	Person 5	Person 6
How long before each person made contact	hours	hours	hours	hours	hours	hours

31 Using the same order as on the last page, please answer which location(s) (if any) each person in your household travelled to in the first 24 hours *after* returning home after the June earthquakes. Please give the reason for going to each location. * *While this is not a social science project but a disaster response and preparedness survey, it is understood that having an injured or deceased household member may affect the other household members' action and travel plans*

	Person 1	Person 2	Person 3	Person 4	Person 5	Person 6
Print 1st location (suburb, town, etc)						
Reason						
Print 2nd location (suburb, town, etc)						
Reason						
Print 3rd location (suburb, town, etc)						
Reason						

32 Using the same order as on the last page, please answer which location(s) (if any) each person in your household evacuated to within seven days of the June earthquakes. Please give their reasons for leaving, the date they left, and how long for. Or, if they stayed at home, please tick the box for the circumstances which best apply.

	Person 1	Person 2	Person 3	Person 4	Person 5	Person 6
	Tick one	Tick one	Tick one	Tick one	Tick one	Tick one
Evacuated...						
by self	☐	☐	☐	☐	☐	☐
by friend/family	☐	☐	☐	☐	☐	☐
by emergency services	☐	☐	☐	☐	☐	☐
Evacuated to where(suburb, town, etc):						
Reason for leaving?						
Date left dwelling (13 - 20)?						
Stayed away for how many days?						
Stayed at home because...						
wanted to (own choice)	☐	☐	☐	☐	☐	☐
needed to (dependents)	☐	☐	☐	☐	☐	☐
had to (no place to go)	☐	☐	☐	☐	☐	☐

33 Did you have dependents in your care at the time of the June earthquakes that required medical attention?

No ☐ go to **35**

Yes ☐

34 Was medical attention available?

Yes – immediately ☐

Yes – within 24 hours ☐

Yes – within three days ☐

No ☐

Unable to recall ☐

35 Did you have animals in your care at the time of the June earthquakes?

No ☐ go to **37**

Yes - small pets (cat, dog, fish, etc) ☐

Yes - livestock (horses, goats, etc) ☐

36 Were you able to tend to your animals during the seven day period following the June earthquakes?

Yes ☐

No ☐

Unable to recall ☐

37 What kind of event(s) do you imagine your household will experience in the future?

Tick all that apply

- Tsunami ☐
- Flooding ☐
- Bushfire/wildfire ☐
- Damaging weather (e.g. cyclone, storm , heavy rainfall, hail, wind, tornado) ☐

Tick all that apply

- Snowstorm ☐
- Earthquake ☐
- Landslide/rock fall ☐
- Explosion/toxic chemical spill/gas leak ☐

Other – please specify ☐

38 Do you currently have any concerns about the likelihood of another natural disaster or civil defence emergency of any kind affecting the safety of your family or property?

- Yes ☐
- No ☐

39 If another disaster were to occur, please rate how each circumstance may influence your decision to evacuate?
(Please tick one box for each circumstance that most closely represents your strength of decision to evacuate)

	Very likely	Likely	Unlikely	Very unlikely
No mains power	☐	☐	☐	☐
No tap water	☐	☐	☐	☐
No heating	☐	☐	☐	☐
No telephone/ Internet	☐	☐	☐	☐
Loss of social network/neighbours	☐	☐	☐	☐
Loss of local shops or amenities	☐	☐	☐	☐
Fear of aftershocks	☐	☐	☐	☐
Home structurally damaged	☐	☐	☐	☐
Need to care for dependents at home	☐	☐	☐	☐
Need to care for dependents elsewhere	☐	☐	☐	☐
No private toilet/ washing facilities	☐	☐	☐	☐
No public transport	☐	☐	☐	☐
Loss of private transport	☐	☐	☐	☐
Roads impassable	☐	☐	☐	☐
Flooding of property	☐	☐	☐	☐
Fear of rock fall/landslide	☐	☐	☐	☐
Lack of emergency services cover	☐	☐	☐	☐
Household financial situation	☐	☐	☐	☐
Mortgage	☐	☐	☐	☐
Work	☐	☐	☐	☐
Having somewhere else to go	☐	☐	☐	☐
Other (please specify):	☐	☐	☐	☐
Other (please specify):	☐	☐	☐	☐

40 We very much appreciate the time you spent and answers you have given. We can understand that answering these questions may bring out emotions and recall memories that are hard to cope with. If you wish to write something in your own words that you believe would help make this research more helpful to others, or simply to act as a poignant reminder, please use the space below. Your remarks may be reprinted **anonymously** as part of the appendices to the study.

Once completed, please return this questionnaire in the reply-paid envelope.

Thank you

Natural Hazards Research Centre
Department of Geological Sciences
College of Science
University of Canterbury
Private Bag 4800,
Christchurch 8140, New Zealand

CENSUS

This enclosed questionnaire is being delivered to all households in

Lyttelton, Corsair Bay, Cass Bay and Rapaki

Disaster Response and Preparedness in Lyttelton

Internet Survey Number:

Disaster Response and Preparedness in Lyttelton

Supported with funding from

Natural Hazards Research Centre, Department of Geological Sciences,
University of Canterbury, Private Bag 4800, Christchurch

You will have recently been invited to participate in a study investigating the preparedness and disaster response of the Lyttelton community following the 22nd February and 13th June earthquakes. We are especially interested in what your household did during the seven days following those earthquakes.

If you have already returned the questionnaire or taken the online version, we would like to say thank you. If you have yet to return the questionnaire, may we ask that you do so in the reply-paid envelope before **19th August 2011**. Alternatively, if you would like to take the online questionnaire, please navigate your web browser to

http://www.nhrc.canterbury.ac.nz/julian_idle.shtml

Internet survey number:

If you have any questions for the research team, please contact us at any time.

Principal researcher: Julian Idle
(julian.idle@pg.canterbury.ac.nz)
http://www.nhrc.canterbury.ac.nz

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Phone: (03) 364-2987 ext 45511
Fax: (03) 364 2769

E. 2010 Parked vehicle census

The parked vehicle census was performed on foot using a Trimble Juno SB handheld, a Windows Mobile data collector with an integrated mapping-grade GNSS receiver, running Trimble TerraSync software. The TerraSync software is loaded with a data dictionary for the data collection task at hand. In this census, vehicles were recorded as point data with the following attributes:

Table E-1 : Data Dictionary Schema for Vehicle census data collection

Attribute	Data type	Data values	Description
Vehicle Registration	Text	maximum 6 characters	If visible, the unique vehicle registration is recorded. This is used to identify the vehicle between the various survey sweeps.
Position	Menu	Road	The vehicle is parked on the carriageway, which may include a parking area. Many roads in Lyttelton are narrow and windy, and many vehicles are parked causing obstruction to emergency services. In the event of an earthquake when roads were even more impassable, quantifying the location of an obstruction by parked vehicles, as well as the likelihood of those cars being driven away as people evacuate, are of interest to emergency services.
		Path	The vehicle is parked such that it obstructs pedestrians on the path. This also includes grass verges and median strips. The majority of vehicles parked on paths and verges were located at or near pinch-points on the road network. Sometimes no parking zones meant vehicles would be parked away from the carriageway.
		Property	The vehicle is parked on private property. This includes parking areas not on the carriageway. Sometimes, the hard stands would be contiguous with the carriageway and therefore represents a possible obstacle for emergency services travelling along the road. In the event of an evacuation, having the vehicle parked away from the road means that to evacuate the vehicle would need to join

Attribute	Data type	Data values	Description
			the traffic flow, perhaps leading to a bottleneck.
		Garage	The vehicle is parked in a private garage. Again, as with being parked on private property, opening the garage doors and entering the traffic flow may cause a bottleneck to form. Also, the garage itself may be susceptible to damage, rendering the vehicle inaccessible or damaged.
Direction	Menu	With flow	The vehicle is parked in the direction of traffic flow, i.e. the driver of a vehicle approaching it would see the left-hand side or rear lights (New Zealand Government 2004b) (clause 6.12).
		Against flow	The vehicle is parked facing oncoming traffic, i.e. the driver of a vehicle approaching it would see the right-hand side or front lights.
		Slant	The vehicle is parked in an orientation that is not parallel or perpendicular to the flow of traffic.
		Perpendicular	The vehicle is parked perpendicular to the flow of traffic. This is common practice on Voelas Road, opposite the school, for instance, due to the steep gradient.
		Forward out	The vehicle is parked such that it would need to drive forward to exit private property or garage in order to join the traffic.
		Reverse out	The vehicle is parked such that it would need to reverse to exit private property or garage in order to join the traffic.
Type	Menu	Car	A car, with seats for between 2 and 7 passengers, and not otherwise categorised, below.
		SUV	A vehicle with higher ground clearance than a car but not capable of off-road travel.
		4x4	A vehicle with permanent or selectable four-wheel drive, with high ground clearance, capable of off-road travel.
		Ute	A vehicle with a tray in lieu of an enclosed luggage space. The tray may have an optional cover. [Ute is derived from *utility*.]
		Van	A vehicle used by contractors or as a small

Attribute	Data type	Data values	Description
			bus with up to 9 passengers.
		Truck	A vehicle used for haulage.
		Trailer	A vehicle with no motor that couples to a pulling vehicle. Includes caravans in this census.
		RV	A recreational vehicle: a motor-powered caravan.
		Machinery	Machinery used for road construction, etc.
		Other	This category consists of motorcycles, mopeds, bicycles. It also includes road obstructions, such as skips.

Figure E-1 : A Trimble Juno SB handheld, running Trimble TerraSync software

After returning from the field, the data was transferred to a computer running Trimble GPS Pathfinder Office software, where it was post-processed against the McQueen's Valley base station, operated by Land Information New Zealand (LINZ).

Data was collected over a period of a few weeks for each day/time combination. Data from the various collection campaigns were merged together to provide a data set for Sunday late afternoons, Monday early afternoons, and Wednesday late evenings.

The resulting, cleaned data was then exported as an Esri ShapeFile to ArcGIS, where it was mapped.

A further bonus of using a GNSS receiver is that elevation data can be collected. Also, a travel log of all points between the vehicles was recorded, meaning the complete public

right of way road network of the study area has been mapped in three dimensions. This census did not include private rights of way.

F. Temporary accommodation – tenancy

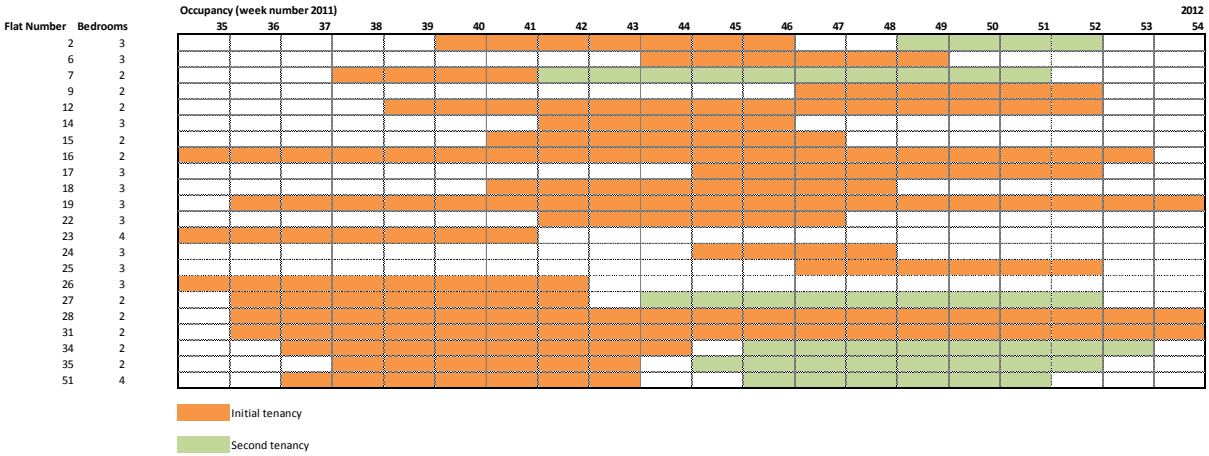

Figure F-1 : Tenancy of temporary housing at Linwood Park (Robertson 2012)

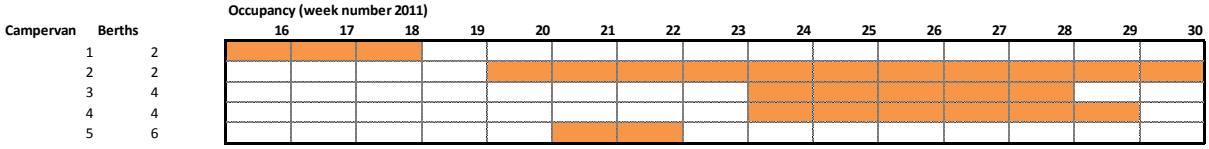

Figure F-2 : Tenancy of campervans sited at Canterbury Agriculture Park (Robertson 2012)

G. Christchurch Suburbs and City Sectors

Suburbs are unofficial unit areas commonly used to describe a locality and are not commonly gazetted. They can be found on various maps as names to describe a general area. Even though suburbs are used for physical post service delivery, they do not have any official meaning. As such, suburbs have not official extents and their boundaries are not officially recognised, and can change depending on use and who is using them.

The smallest official unit area is that of the Statistics New Zealand mesh block. All official unit areas are built using mesh blocks: census blocks, wards, territorial units, etc. The boundaries of New Zealand Post postcode areas are the exception and are based on physical boundaries and do not follow either mesh block or suburb 'boundaries'.

This study lists 81 localities and treats them as suburbs.

These suburbs have then been aggregated for this analysis to create City Sectors. For this study, the main population centres of the study area have been left separate and identifiable.

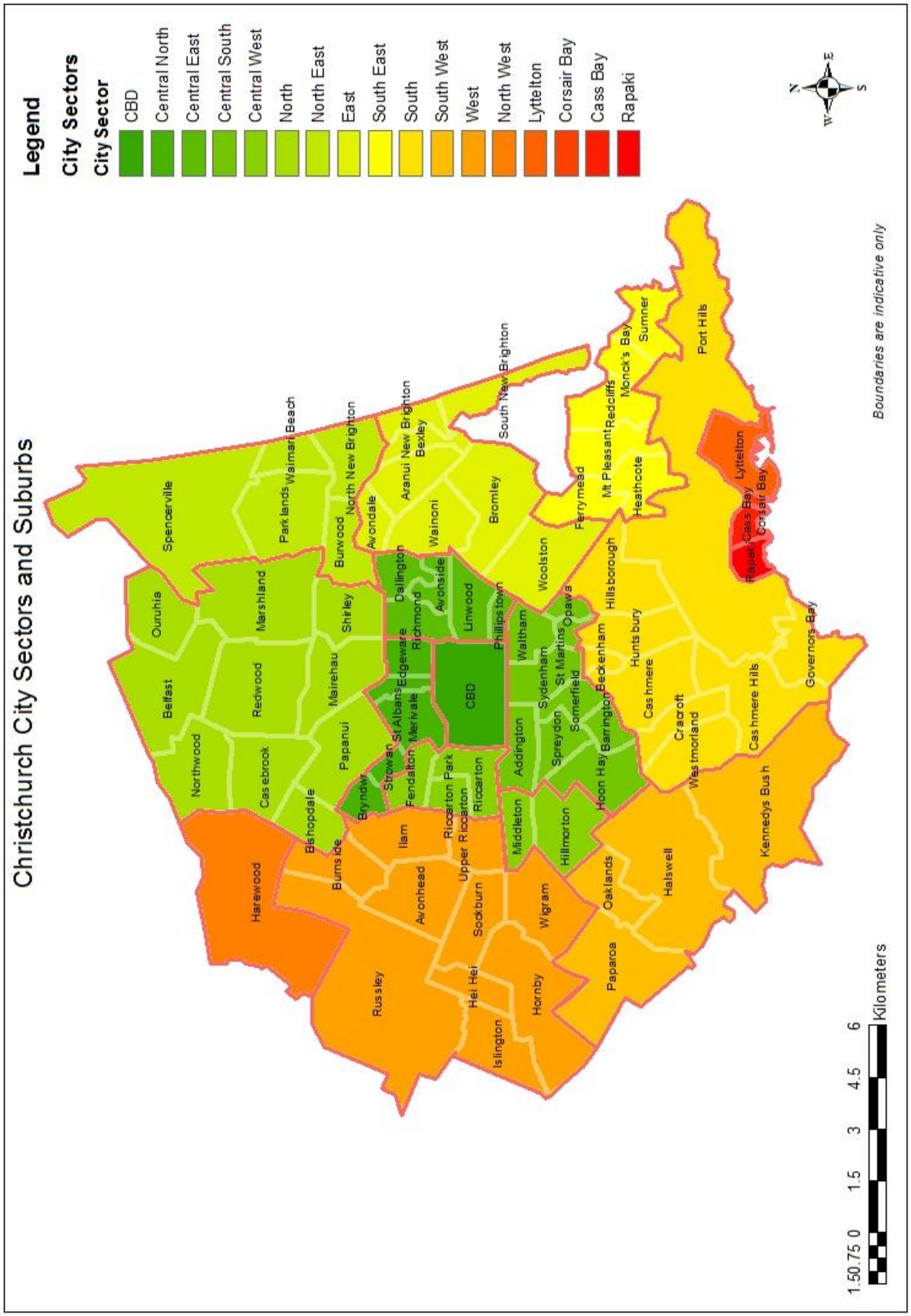

Figure G-1 : Christchurch city sectors

H. Housing stock

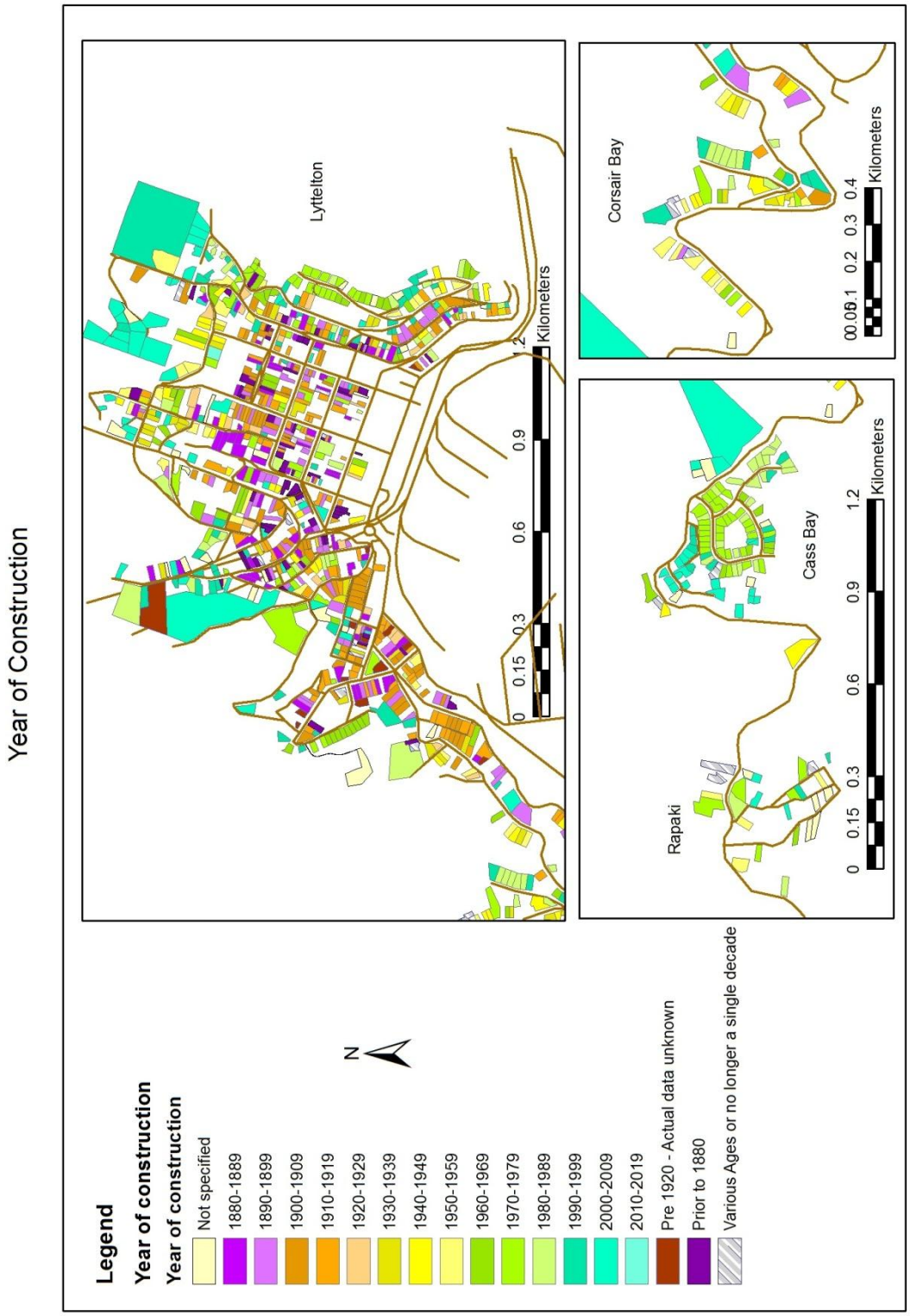

Figure H-1 : Year of construction of buildings in the study area

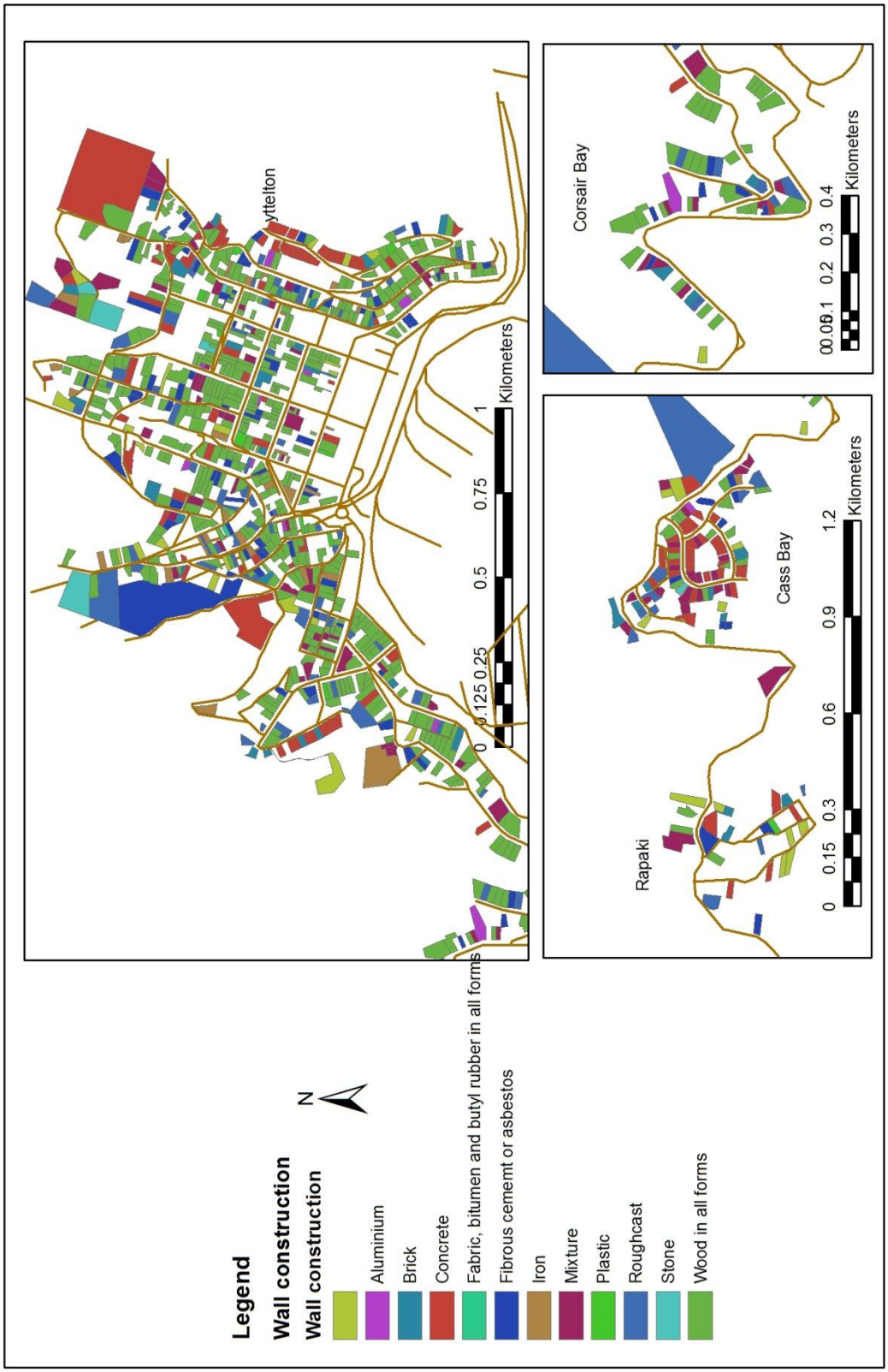

Figure H-2 : Wall construction of buildings in the study area

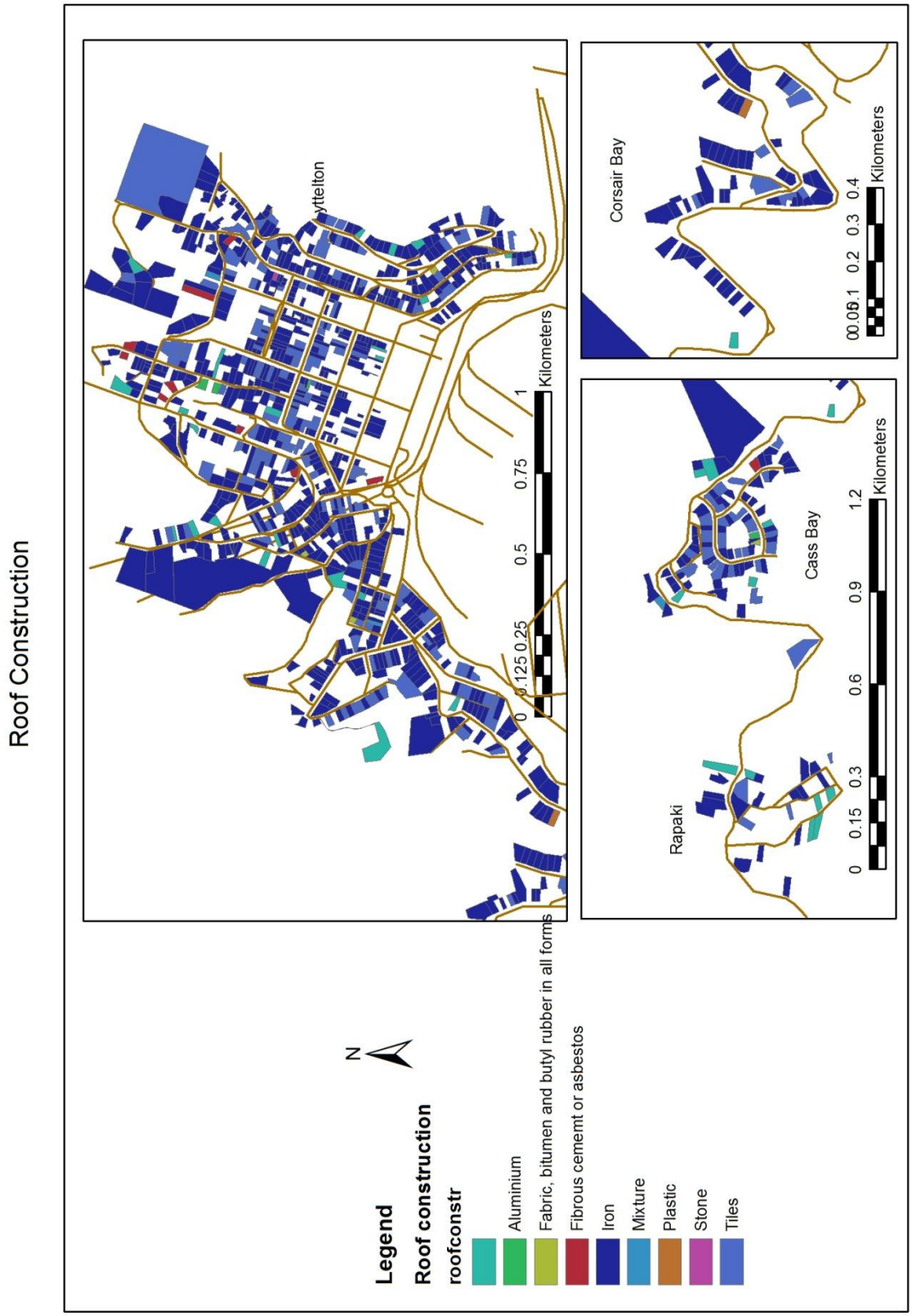

Figure H-3 : Roof construction of buildings in the study area

I. Study area red/yellow/green sticker map, with demolitions

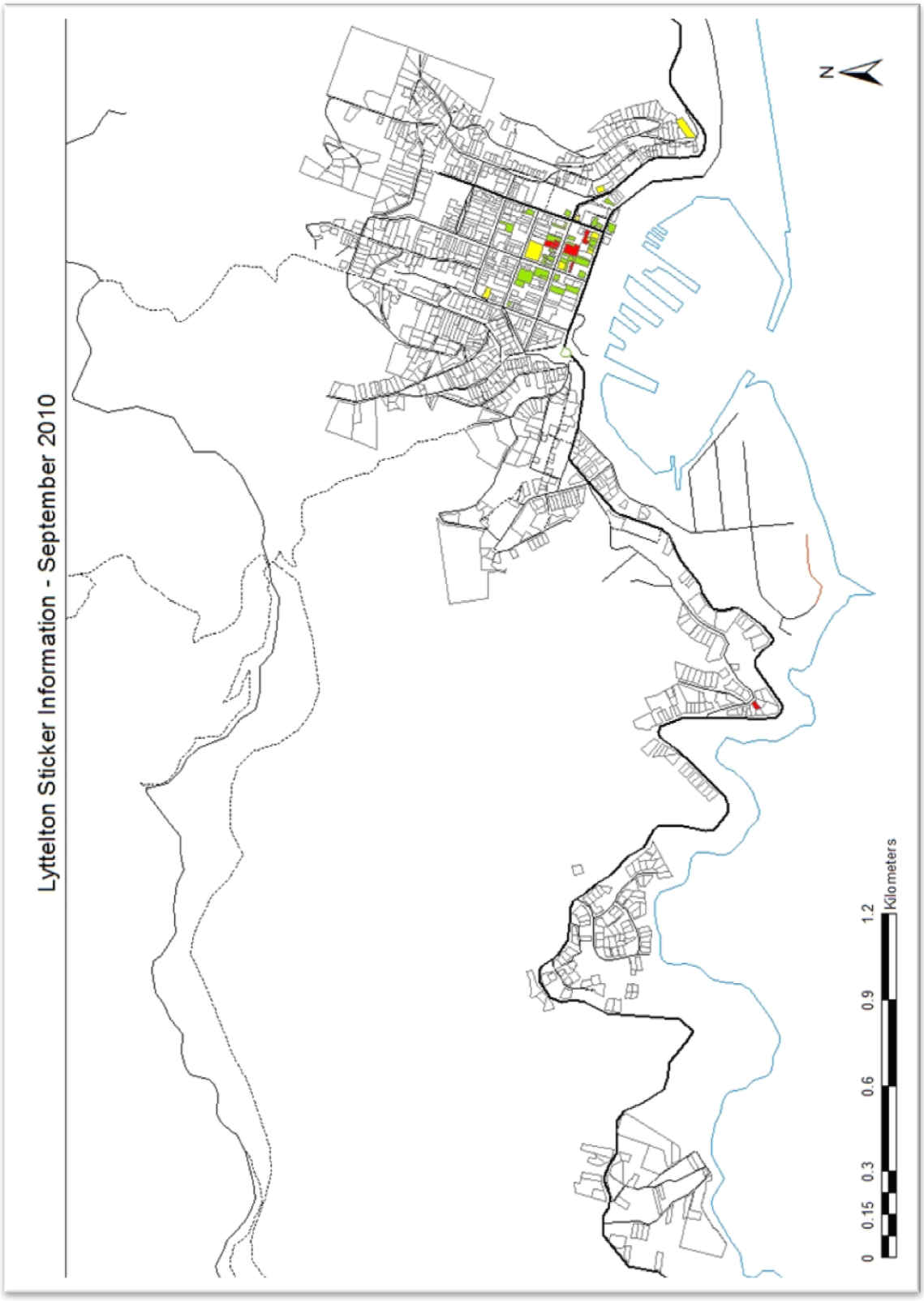

Figure I-1 : Building placard placement – September 2010

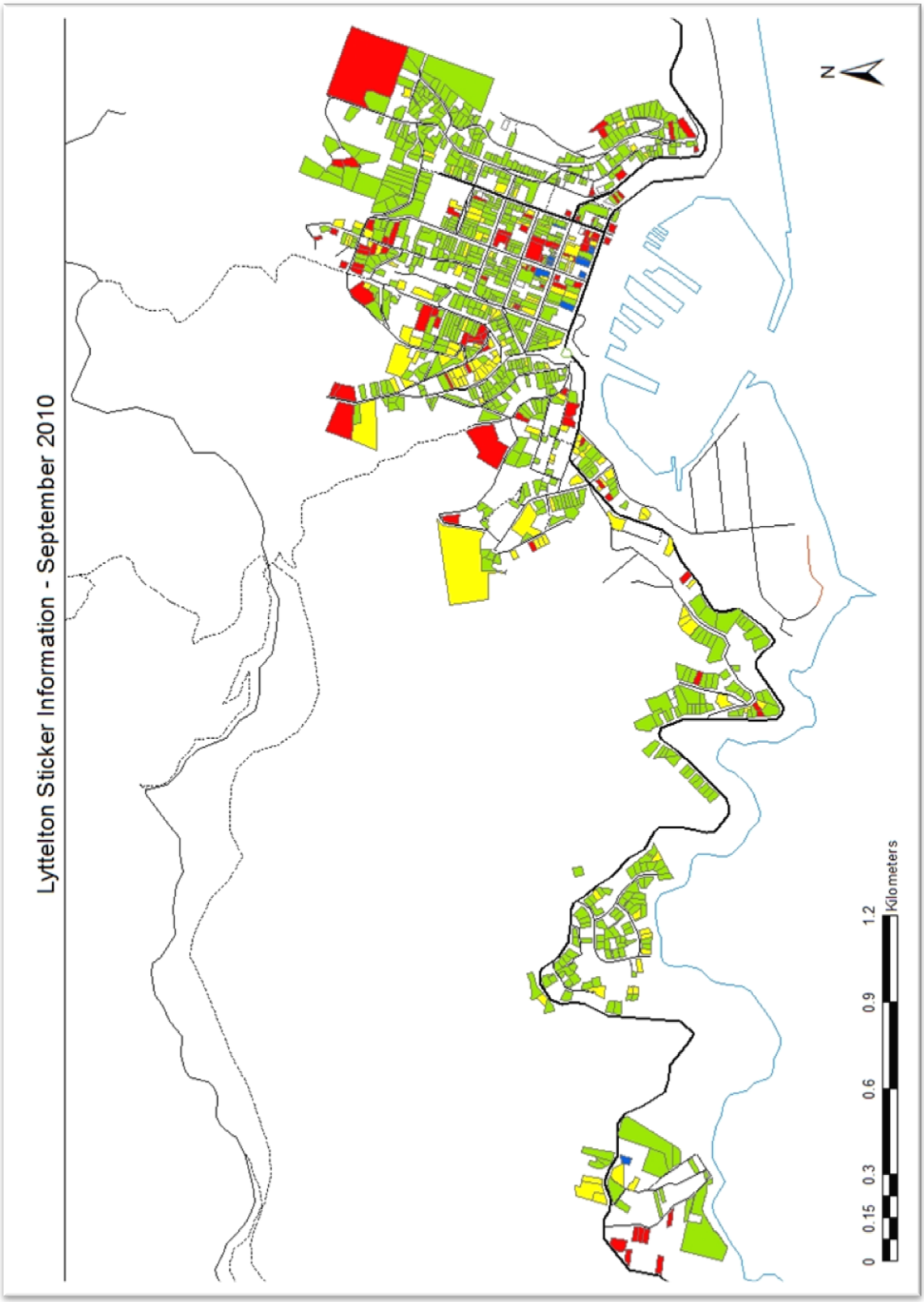

Figure I-2 : Building placard placement – February 2011

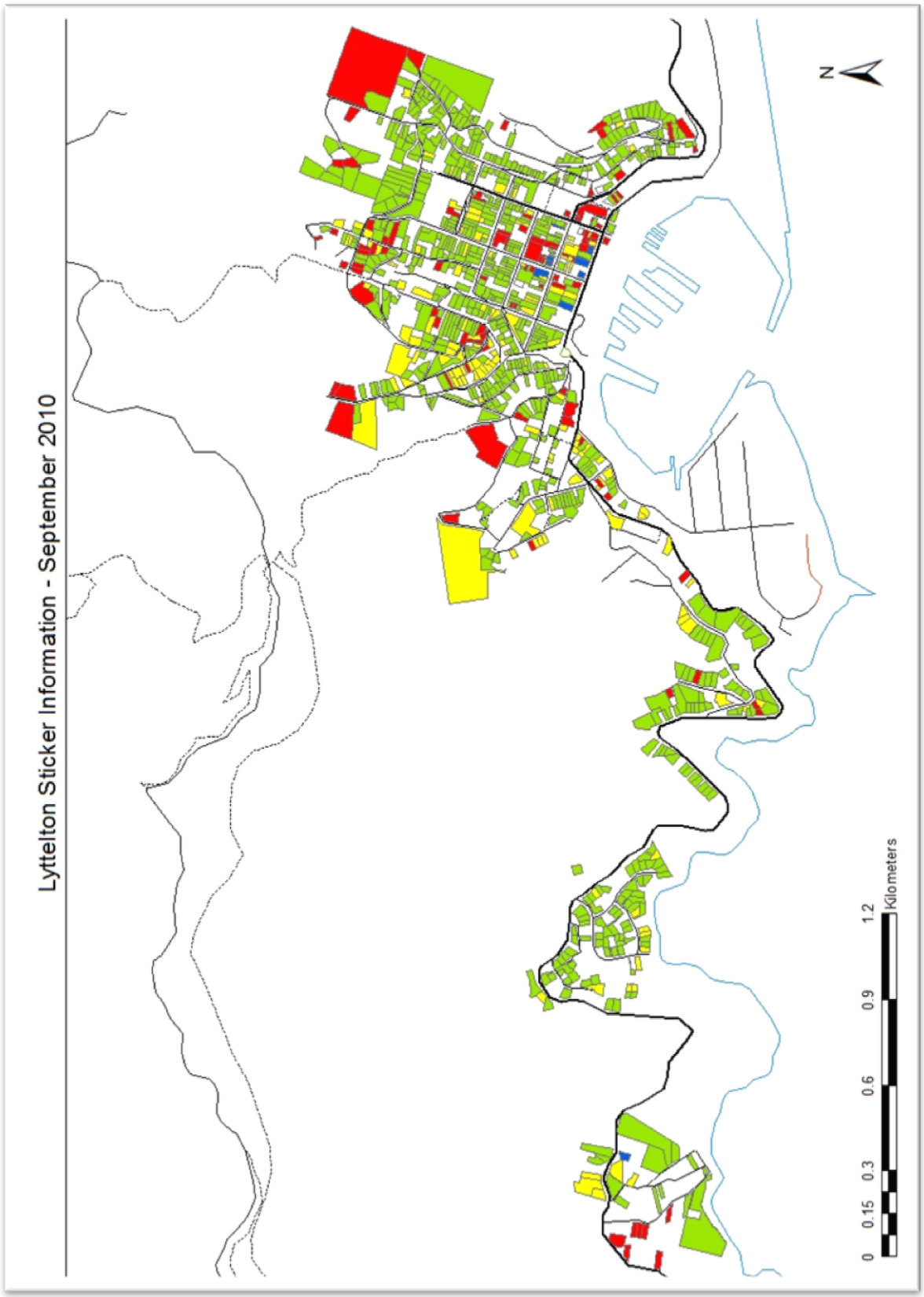

Figure I-3 : Building placard placement – June 2011

J. New Zealand Modified Mercalli Scale

The following table is taken from (Dowrick 1996).

Table J-1 : New Zealand Modified Mercalli Scale

Level	Description
MM I	*People* Not felt except by a very few people under exceptionally favourable conditions.
MM II	*People* Felt by persons at rest, on upper floors or favourably placed.
MM III	*People* Felt indoors; hanging objects may swing, vibration similar to passing of light trucks, duration may be estimated, may not be recognised as an earthquake.
MM IV	*People* Generally noticed indoors but not outside. Light sleepers may be awakened. Vibration maybe likened to the passing of heavy traffic, or to the jolt of a heavy object falling or striking the building. *Fittings* Doors and windows rattle. Glassware and crockery rattle. Liquids in open vessels may be slightly disturbed. Standing motorcars may rock. *Structures* Walls and frames of buildings, and partitions and suspended ceilings in commercial buildings, may be heard to creak.
MM V	*People* Generally felt outside, and by almost everyone indoors. Most sleepers awakened. A few people alarmed. *Fittings* Small, unstable objects are displaced or upset. Some glassware and crockery may be broken. Hanging pictures knock against the wall. Open doors may swing. Cupboard doors secured by magnetic catches may open. Pendulum clocks stop, start, or change rate. *Structures* Some windows Type I cracked. A few earthenware toilet fixtures cracked.
MM VI	*People* Felt by all. People and animals alarmed. Many run outside. Difficulty experienced in walking steadily. *Fittings* Objects fall from shelves. Pictures fall from walls. Some furniture moved on smooth floors, some unsecured free-standing fireplaces moved. Glassware and crockery broken. Very unstable furniture overturned. Small church and school bells ring. Appliances move on bench or table tops. Filing cabinets or “easy glide” drawers may open (or shut). *Structures* Slight damage to buildings Type I. Some stucco or cement plaster falls. Windows Type I broken. Damage to a few weak chimneys, some may fall. *Environment* Trees and bushes shake, or are heard to rustle. Loose material may be dislodge from sloping ground, e.g. existing slides, talus slopes, shingle slopes.
MM VII	*People* General alarm. Difficulty experienced in standing. Noticed by motorcar drivers who may stop. *Fittings* Large bells ring. Furniture moves on smooth floors, may move on carpeted floors. Substantial damage to fragile contents of buildings. *Structures* Unreinforced stone and brick walls cracked. Building Type I cracked with some minor masonry falls. A few instances of damage to Buildings Type II. Unbraced parapets, unbraced brick girdles, and architectural ornaments fall. Roofing tiles, especially ridge tiles may be dislodged. Many unreinforced domestic chimneys damaged, often falling from roof-line. Water tanks Type I burst. A few instances of damage to brick veneers and plaster or cement-based linings. Unrestrained water cylinders (water tanks Type II) may move and leak. Some windows Type II cracked. Suspended ceilings fall. *Environment* Water made turbid by stirred-up mud. Small slides such as falls of sand or gravel banks, and small rock-falls from steep slopes and cuttings. Instances of settlement of unconsolidated or wet, weak soils. Some fine cracks appear in sloping ground. A few instances of liquefaction (i.e. small water and sand ejections).

Level	Description
MM VIII	*People* Alarm may approach panic. Steering of motorcars greatly affected. *Structures* Buildings Type I heavily damaged, some collapse. Buildings Type II damaged, some with partial collapse. Buildings Type III damaged in some cases. A few instances of damage to Structure Type IV. Monuments and pre-1976 elevated tanks and factory stacks twisted or brought down. Some pre-1965 infill masonry panels damaged. A few post-1980 brick veneers damaged. Decayed timber piles of houses damaged. Houses not secured to foundations may move. Most unreinforced domestic chimneys damaged, some below roof-line, many brought down. *Environment* Cracks appear on steep slopes and in wet ground. Small to moderate slides in roadside cuttings and unsupported excavations. Small water and sand ejections and localised lateral spreading adjacent to streams, canals, lakes, etc.
MM IX	*Structures* Many Buildings Type I destroyed. Buildings Type II heavily damaged, some collapse. Buildings Type III damaged, some with partial collapse. Structures Type IV damaged in some cases, some with flexible frames seriously damaged. Damage or permanent distortion to some Structures Type V. Houses not secured to foundations shifted off. Brick veneers fall and expose frames. *Environment* Cracking of ground conspicuous. Landsliding general on steep slopes. Liquefaction effects intensified and more widespread, with large lateral spreading and flow sliding adjacent to streams, canals, lakes, etc.
MM X	*Structures* Most Buildings Type I destroyed. Many Buildings Type II destroyed. Buildings Type III heavily damaged, some collapse. Structures Type IV damaged, some with partial collapse. Structures Type V moderately damaged, but few partial collapses. A few instances of damage to Structures Type VI. Some well-built timber buildings moderately damaged (excluding damage from falling chimneys). *Environment* Landsliding very widespread in susceptible terrain, with very large rock masses displaced on steep slopes. Landslide dams may be formed. Liquefaction effects widespread and severe.
MM XI	*Structures* Most Buildings Type II destroyed. Many Buildings Type III destroyed. Structures Type IV heavily damaged, some collapse. Structures Type V damaged, some with partial collapse. Structures Type VI suffer minor damage, a few moderately damaged.
MM XII	*Structures* Most Buildings Type III destroyed. Structures Type IV heavily damaged, some collapse. Structures Type V damaged, some with partial collapse. Structures Type VI suffer minor damage, a few moderately damaged.

Construction types

Buildings Type I	Buildings with low standard of workmanship, poor mortar, or constructed of weak materials like mud brick or rammed earth. Soft storey structures (e.g. shops) made of masonry, weak reinforced concrete or composite materials (e.g. some walls timber, some brick) not well tied together. Masonry buildings otherwise conforming to buildings Types I to III, but also having heavy unreinforced masonry towers. (Buildings constructed entirely of timber must be of extremely low quality to be Type I.)
Buildings Type II	Buildings of ordinary workmanship, with mortar of average quality. No extreme weakness, such as inadequate bonding of the corners, but neither designed nor reinforced to resist lateral forces. Such buildings not having heavy unreinforced masonry towers
Buildings Type III	Reinforced masonry or concrete buildings of good workmanship and with sound mortar, but not formally designed to resist earthquake forces.
Structures Type IV	Buildings and bridges designed and built to resist earthquakes to normal use standards, i.e. no special collapse or damage limiting measures taken (mid-1930s to c. 1970 for concrete and to c. 1980 for other materials).
Structures Type V	Buildings and bridges, designed and built to normal use standards, i.e. no special damage limiting measures taken, other than code requirements, dating from since c. 1970 for concrete and c. 1980 for other materials.
Structures Type VI	Structures, dating from c. 1980, with well-defined foundation behaviour, which have been specially designed for minimal damage, e.g. seismically isolated emergency facilities, some structures with dangerous or high contents, or new generation low damage structures.

Windows

Type I	Large display windows, especially shop windows
Type II	Ordinary sash or casement windows

Water tanks

Type I	External, stand mounted, corrugated iron tanks
Type II	Domestic hot-water cylinders unrestrained except by supply and delivery pipes.

Other comments

- "Some" or "a few" indicates that the threshold of a particular effect has just been reached at that intensity.
- "Many run outside" (MM 6) is variable depending upon mass behaviour, or conditioning by occurrence or absence of previous earthquakes, i.e. may occur at MM 5 or not until MM 7.
- "Fragile contents of buildings": fragile contents include weak, brittle, unstable, unrestrained objects in any kind of building.
- "Well-built timber buildings" have: wall openings not too large; robust piles or reinforced concrete strip foundations; superstructure tied to foundation.
- Buildings Type III to V at MM 10 and greater intensities are more likely to exhibit the damage levels indicated for low-rise buildings on firm or stiff ground and for high-rise buildings on soft ground. By inference lesser damage to low-rise buildings on soft ground and high-rise buildings on firm or stiff ground may indicate the same intensity. These effects are due to attenuation of short period vibrations and amplification of longer period vibrations in soft soils.

K. Source data

Table K-1 : Data sources used in this thesis

Data description	Source
Parcel boundaries	Christchurch City Council (CCC)
Red/Yellow/Green Sticker	Christchurch City Council
QV Data	Christchurch City Council
Demolition data	Canterbury Earthquake Recovery Authority (CERA)
Rockfall threat data	Port Hills Geotechnical Group (PHGG)/(CCC)
Lyttelton tunnel closures	New Zealand Transport Agency (NZTA)
Lyttelton-area road use data	Christchurch City Council
Road condition data	Christchurch City Council
Satellite imagery	Google Earth
Topo-Maps	TopoOnline
Coastline data	Koordinates
Meshblock	Statistics New Zealand
Deprivation Index	Otago University, Ministry of Health

L. Non-Disclosure Agreement (NDA)

Some geotechnical obtained for use in the rock fall and land slide hazard analysis was obtained from the Port Hills Geotechnical Group, a working group which is part of the Christchurch City Council, under a non-disclosure agreement between the CCC and University of Canterbury. That source data cannot be published, however it is possible to publish the data in an aggregate form that is not site specific. The NDA is attached, herewith, as a record.

Non-Disclosure Agreement

between
Christchurch City Council
and
University of Canterbury

ANDERSONLLOYD
LAWYERS

Non-Disclosure Agreement

Date: 2011

Parties

1. **Christchurch City Council** ("Discloser")

2. **University of Canterbury** ("Recipient")

Background

A. The Discloser has agreed to disclose certain information to the Recipient in relation to the Purpose described below.

B. This agreement sets out the terms on which these disclosures will be made.

This agreement records

1. **Interpretation**

1.1 In this deed:

"**Confidential Information**" means all information and data of whatever nature in, directly or indirectly concerning the database "Data Collection of Geotechnical Features in the Port Hills" (including any data, study, analysis or model developed from such database) which the Discloser supplies or discloses to the Recipient or which the Recipient may acquire from the Discloser or any of its Related Companies including, without limitation:

a. any intellectual property, including any opinion, projection, idea, concept, process, procedure, plan, design, programme, study, data, report, know-how, expertise or other such property; and

b. any document, data, statement, analysis, opinion, projection, forecast, report, note, notebook, drawing, manual, letter or such other material whether in a permanently visible form or not;

but excludes:

a. information that as of the date of disclosure is in the public domain or subsequently enters the public domain without fault on the part of the Recipient;

b. information that at any time is received in good faith by the Recipient from a third party which was lawfully in possession of and had the right to disclose the information and did so without any limitation on confidentiality.

"**Person**" includes a natural person, individual, firm, company, corporation, association or other entity, whether incorporated or not.

"**Purpose**" means the development ,creation and publication of a written research report, including all drafts, ("Research Report") by Julian Idle with co – supervisors Dr Thomas Wilson and Professor Tim Davies under the supervision and auspices of the Recipient (but not otherwise by third parties).

2. **Confidentiality undertakings**

2.1 The Recipient agrees to receive the Confidential Information in the strictest confidence and to keep the Confidential Information strictly confidential and to take all steps to prevent any unauthorised use or disclosure of the Confidential Information. Without limiting the preceding sentence, the Recipient will not at any time:

a. disclose, distribute or permit to be disclosed or distributed the Confidential Information to any Person (including any officer, employee, agent or advisor of or to the Discloser); or

b. in any way use the Confidential Information for any purpose other than the Purpose; or

c. assert any rights of any nature in respect of, or contest the Discloser's ownership of, the Confidential Information.

In addition to the undertakings given in clause 2.1, the Recipient undertakes and shall be responsible for the strict supervision of specific data (being part of the Confidential Information) being released to Julian Idle, Dr Thomas Wilson and Professor Tim Davies only; any reference to such data in the Research Report (including all ancillary and draft documentation) shall be in the aggregate form and not site specific and the Recipient acknowledges that the data shall only be used for the Purpose and is provided on the basis that the data is subject to change, alteration and amendment from time to time.

3. Assessment of confidential information

3.1 The Recipient acknowledges that the Confidential Information will be provided to it solely for the Purpose and shall not be used by the Recipient for any other purpose. The Confidential Information will be supplied via the Discloser's consultants and the Recipient acknowledges that a process will need to be followed by the Discloser in furnishing the Confidential Information to the Recipient.

3.2 The Recipient shall not copy or reproduce any Confidential Information in any way, except with the prior written consent of the Discloser.

3.3 The Recipient agrees that it is solely responsible for its own assessment and evaluation of the Confidential Information and the Discloser does not warrant or represent the accuracy, adequacy or completeness of any of the Confidential Information.

3.4 The Recipient acknowledges that this agreement creates no obligation on the Discloser to give any particular information, or to contract with the Recipient, or otherwise engage or enter into any arrangement of any sort with the Recipient.

4. Disclosure required by law

4.1 If the Recipient is legally required to disclose any Confidential Information, the Recipient will:

a. immediately notify the Discloser of such requirements; and

b. fully cooperate with all legal actions taken by the Discloser to avoid or limit such disclosure.

4.2 If the Discloser cannot avoid such disclosure, the Recipient will:

a. only disclose such portions of the Confidential Information as are legally required to be disclosed by law; and

b. use its best endeavours to obtain assurances that such information will be treated as confidential by any Person to whom it is disclosed.

5. Indemnity

5.1 The Recipient will indemnify the Discloser from and against all actions, claims, costs (including all reasonable legal, accounting, and other professional fees), demands,

expenses, liabilities, losses, payments and proceedings whatsoever incurred or suffered by them which arise from or by virtue of the unauthorised disclosure or use of the Confidential Information by the Recipient any of their respective officers or employees or any such Persons otherwise being in breach of any of the provisions of this agreement.

6. Return and/or Destruction of Confidential Information

6.1 The Recipient will at any time upon the Discloser's written request:

a. subject to any requirement to the contrary provided at law, promptly return or destroy (at the direction of the Discloser) all Confidential Information in the Recipient's possession or in the possession of anyone to whom it has disclosed the information under this agreement; and

b. execute and deliver to the Discloser a certificate confirming compliance with this clause. This certificate must state either:

i. the items returned comprise all the Confidential Information in the Recipient's possession or control; or

ii. that destruction has occurred in the presence or under the supervision of an authorised officer of the Recipient who is making the certification.

7. Remedies

7.1 In addition to any other rights or remedies to which the Discloser may be entitled under this agreement or otherwise at law, the Recipient, in recognition of the injury which could be caused to the Discloser if Confidential Information is disclosed and in recognition that damages may be an insufficient remedy for such a breach of confidence, consents to the issue of an injunction or other order specifically enjoining the Recipient or any other Person from engaging in any action in breach of the terms of this agreement.

8. Non-Assignment

8.1 The Recipient agrees not to assign, transfer or otherwise dispose of all or any of its rights under this agreement or to deal with those rights on behalf of any other person.

9. Term

9.1 The obligations as to confidentiality and use of the Confidential Information in this agreement remain in full force and effect for a period of five years from the date of this agreement.

10. General

10.1 No waiver by the Discloser of any provision of or right, remedy or power of the Discloser under this agreement, and no amendment to this agreement will be effective unless it is in writing signed by the Discloser. Any such waiver will be effective only in the specified instance and for the specific purpose for which it is given. No failure or delay by the Discloser to exercise any right, remedy or power under this agreement or to insist on strict compliance by the Recipient with any obligation under this agreement, and no custom or practice of the parties at variance with the terms of this agreement, will constitute a waiver of the Discloser's to any of its Related Companies' right to demand exact compliance with this agreement.

10.2 If any provision of this deed becomes invalid and unenforceable for any reason, the remaining provisions will remain valid and enforceable.

10.3 This agreement is governed by and in accordance with the laws of New Zealand. The Recipient submits to the exclusive jurisdiction of the courts of New Zealand in the interpretation and enforcement of this agreement.

Signed by the parties

Signed by **Christchurch City Council** as Discloser by its duly authorised signatories in the presence of:

L. Howard
Signature of witness

Authorised person's signature

Full name of witness

Authorised person's signature

Lorraine Howard.
Occupation

PA to GM RDS Group.
Address

PO Box 73016
Christchurch.

Peter Mitchell
General Manager
Regulation and Democracy
Services Group

Signed by **University of Canterbury** as Recipient by its duly authorised signatories in the presence of:

Signature of witness

(John Duncan)
Authorised person's signature

Carmel Howley
Full name of witness

Authorised person's signature

Business Development Manager
Occupation

University of Canterbury
Address
Christchurch.

M. Human Ethics Committee approvals

Human Ethics Committee
Tel: +64 3 364 2241, Fax: +64 3 364 2856, Email: human-ethics@canterbury.ac.nz

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Ref: HEC 2010/40/LR

28 June 2010

Julian Idle
Department of Geological Sciences
UNIVERSITY OF CANTERBURY

Dear Julian

Thank you for forwarding to the Human Ethics Committee a copy of the low risk application you have recently made for your research proposal "Origin-destination traffic study: Lyttelton".

I am pleased to advise that this application has been reviewed and I confirm support of the Department's approval for this project.

As outlined in the email to you from Mike Grimshaw, if access to existing video log positions at Lyttelton Road tunnel portal occurs, then there needs to be an information sheet for who controls these and a consent form for access, use and storage of video logs arising from this.

With best wishes for your project.

Yours sincerely

PP Dr Michael Grimshaw
Chair, Human Ethics Committee

Human Ethics Committee
Tel: +64 3 364 2241, Fax: +64 3 364 2856, Email: human-ethics@canterbury.ac.nz

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Ref: HEC 2010/100

16 August 2010

Julian Idle
Department of Geological Sciences
UNIVERSITY OF CANTERBURY

Dear Julian

The Human Ethics Committee advises that your research proposal "Hazard resilience survey/questionnaire, Lyttelton" has been considered and approved.

Please note that this approval is subject to the incorporation of the amendments you have provided in your email of 9 August 2010.

Best wishes for your project.

Yours sincerely

PP Dr Michael Grimshaw
Chair, Human Ethics Committee

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

HUMAN ETHICS COMMITTEE

Secretary, Lynda Griffioen
Email: human-ethics@canterbury.ac.nz

Ref: HEC 2011/39

13 June 2011

Julian Idle
Department of Geological Sciences
UNIVERSITY OF CANTERBURY

Dear Julian

The Human Ethics Committee advises that your research proposal "Population preparedness to evacuate - questionnaire, Lyttelton" has been considered and approved.

Please note that this approval is subject to the incorporation of the amendments you have provided in your email of 2 June 2011.

This approval is subject to the following:

- Please include the following statement in the relevant document(s): "While this is not a social science project but a disaster response and preparedness survey, it is understood that having an injured or deceased household member may affect the other household members' action and travel plans."
- Please note that the results of this survey have been approved for open ended use by associated research.

Best wishes for your project.

Yours sincerely

Michael Grimshaw
Chair
University of Canterbury Human Ethics Committee

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

HUMAN ETHICS COMMITTEE

Secretary, Lynda Griffioen
Email: human-ethics@canterbury.ac.nz

Ref: HEC 2011/39

20 June 2011

Julian Idle
Department of Geological Sciences
UNIVERSITY OF CANTERBURY

Dear Julian

Thank you for your request for an amendment to your research proposal "Population preparedness to evacuate - questionnaire, Lyttelton".

I am pleased to advise that this request has been considered and approved by the Human Ethics Committee.

Yours sincerely

Michael Grimshaw
Chair
University of Canterbury Human Ethics Committee

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

HUMAN ETHICS COMMITTEE

Secretary, Lynda Griffioen
Email: human-ethics@canterbury.ac.nz

Ref: HEC 2011/39

15 August 2011

Julian Idle
Department of Geological Sciences
UNIVERSITY OF CANTERBURY

Dear Julian

Thank you for your request for an amendment to your research proposal "Population preparedness to evacuate - questionnaire, Lyttelton".

I am pleased to advise that this request has been considered and approved by the Human Ethics Committee.

Yours sincerely

Michael Grimshaw
Chair
University of Canterbury Human Ethics Committee